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TRANSMISSION OF INTELLIGENCE ON STEAM VESSELS.

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COMMUNICATION on steam vessels divides itself into signals for navigational protection from other craft and means whereby it may securely provide for its own safe carriage of human life and cargo; on the one hand exterior communication to ward off collision, as well as maintain its own legal course, on the other interior communication for the proper, lawful and safe manipulation of the vessel and the accommodation of her passengers, officers, and crew. Exterior communications required by law are: Running and anchor lights, searchlights (in some instances), steam whistle, siren fog whistle, rockets, etc. Wireless telegraphy, submarine signals, night signal sets, electric flash lights for steam whistle, are carried on many vessels to-day as a greater factor of safety. The scope of this paper will not permit even a brief description of these systems, if indeed a brief descrip-

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tion could be made, and attention will be addressed solely to the reasons for, and the present means of, interior communication on steam vessels.

It is generally known that steam vessels vary greatly in type. Therefore a standard steamship is but the immaterial mind-wanderings of the hopeful shipbuilder—he who would like to manufacture ships as they do screws, or pens. But it does not occur to many that other than the varying types the vessel usually is for some particular or special service. Thus one might fancy that a number of ships designed exactly alike in regard to form, line, propulsion, etc., and yet for a different service, must, to satisfy this service, be very differently equipped. So passenger and freight vessels for our coastwise shipping, though resembling transatlantic Leviathans, employ docking telegraphs because they can more economically and time-sparingly enter their docks. The transatlantic and transpacific vessels, due to their size or due to the docking facilities, depend upon tug-boats for these manœuvres. Ferry-boats which are constantly coming in or going out of their slips are provided especially with direction tell-tales which assure the pilot that the engines are rotating in such manner that the boat will advance when he has signaled for ahead motion. Avoidance of serious mishap is thus accomplished. River excursion steamers, whose superstructures are built entirely of wood, thereby requiring great vigilance for the detection of misanthropic fires, are supplied with a complete fire-alarm equipment, this system being so designed that hardly a square yard of the vessel is not guarded by such an appliance. For the assurance of the travelling public it may be well to note here that many of these vessels also carry a sprinkler system such as is now required in many of our land factories. Dredges which hold their working position by means of wooden poles (called spuds), which must be manipulated as their work progresses, require spud telegraphs which convey signals from the working platform to the men employed to raise or lower the spuds. So could be multiplied instances of differences in communication equipment for differences in service. Tempting as this subject is, the duty lies before us to describe the means of this communication and not its varying application.

Electricity holds an important place in the transmission of ships' signals, but this place is secondary as regards the move-

ments of the vessels. Those signals which are necessary to navigation and manœuvring of the vessel are performed mechanically. The control of the main propelling engines from the bridge or pilot-house is accomplished by mechanical transmitters connected by bronze wire to receivers in the engine room. Wheels are encased in each instrument traversed by brass chains. To the ends of these chains the bronze wire is attached. Where corners are encountered triple linked brass chains are led over brass pulleys. In all cases reply signals are transmitted in order that no confusion may arise. The cycle is thus:—Pilot house orders full speed ahead. Engine room replies by bringing arrow attached to handle to the same order. This latter is performed before the actual movement is given to the engine. The markings on the dials are usually of the same character, namely: "Stop," "Stand by," "Slow," "Half speed," "Full speed," "Ahead," and the same "Astern." The dials used on naval vessels differ a trifle, thus: "Stop," "Slow," "Half," "Full" on back motion, "Slow," "Half," "Standard," "Full" on ahead motion. The dials of the transmitters for naval vessels, on account of gun shock, are made of a cast-brass frame work with the openings filled in with heavy transparent celluloid. Those for the merchant marine are fitted with white porcelain, the orders filled in with black enamel. They are illuminated by electric or oil lamps of small candle power. The receivers in the engine room are entirely of brass with the orders deeply cut in and filled for the "Ahead" and "Stop" divisions with black enamel and on the "Astern" divisions red. The dials of standard transmitters are 12 inches in diameter and receivers about 16 inches in diameter. Smaller sized machines are recommended only for small craft, such as have pilot-houses too small to accommodate the standard sizes.

These instruments naturally superseded the ordinary brass gong and jingle bell in so much as they were the more readily operated and provided a great reliability. To-day steamship rules require and naval vessels carry gongs and jingle bells as auxiliaries to the mechanical telegraphs in case of derangement of the latter. They are also required by law to have a "tube of proper size so arranged as to return the sound of the gong to the pilot-house." This practice is justified by experience. The detail as will be clearly recognized is truly serious; for not only

is human life endangered, but incalculable damage will result if these signals are not correctly transmitted when docking the vessel.

Working upon the same principles as described above and resembling in outward appearance the engine telegraphs, there are installed on merchant vessels docking, steering, helm, and engine direction telegraphs. Docking and steering telegraphs are usually combined in one instrument. Two handles are employed, one on the right hand and one on the left hand of the head, the dial on one side giving the steering orders in degrees of the helm and on the other side the requisite orders for docking. The two instruments, one located on the navigating bridge and the other aft near the hand-steering wheel, are identical. They are not arranged for reply but can transmit signals in either direction. The orders for docking are interesting to a land-lubber because of their peculiar sailor characteristics, namely: "Stop engines," "Slow ahead," "Slow astern," "Not clear," "All clear," "Heave away," "Slack away," "Hold on," "Let go," "Make fast," "Avast heaving," all expressions which, floating back in memory to the days of the wooden ship of small dimensions, were transmitted through the air by the sonorous voice of the captain, whose orders echoed back from the obedient quartermaster. To-day no sound is heard. The scene has lost its dramatic interest.

A band attached directly to the rudder stock indicates in the pilot-house or on the bridge the exact angle of the rudder. This is the helm indicator. In like manner the engine direction indicator is connected to the reversing shaft of the main engine so that automatically the signal is transmitted when the engineer sets his engine for the given direction. Docking telegraphs are not in service on naval vessels at the present time, but steering telegraphs, helm indicators and engine direction indicators are customarily installed. Here electrical telegraphs take the place of the mechanical. They will be described subsequently more in detail.

Voice tubes of brass are required by law as auxiliary to the engine mechanical telegraphs. The law is usually fulfilled on merchant vessels by such communication between the pilot house bridge and engine room and also between the chief engineer's room and the engine room. On naval vessels the requirements

far exceed this and will be treated later. The reliability of the voice tube between the engine room and bridge is altogether shattered by two elements which have not been overcome to-day, and which, as can plainly be seen, are almost beyond solution—the internal vibrations and noises of the propelling machinery and the wind whistling down the pipe from the exposed position of the tube on the bridge. For this latter cause swivel mouthpieces have been tried with no appreciable effect; for the former, insulated cushions where the tube attaches to hull have been employed with only greater detriment. Flexible rubber mouthpieces of three or four feet in length are installed at certain termini for convenience and portability.

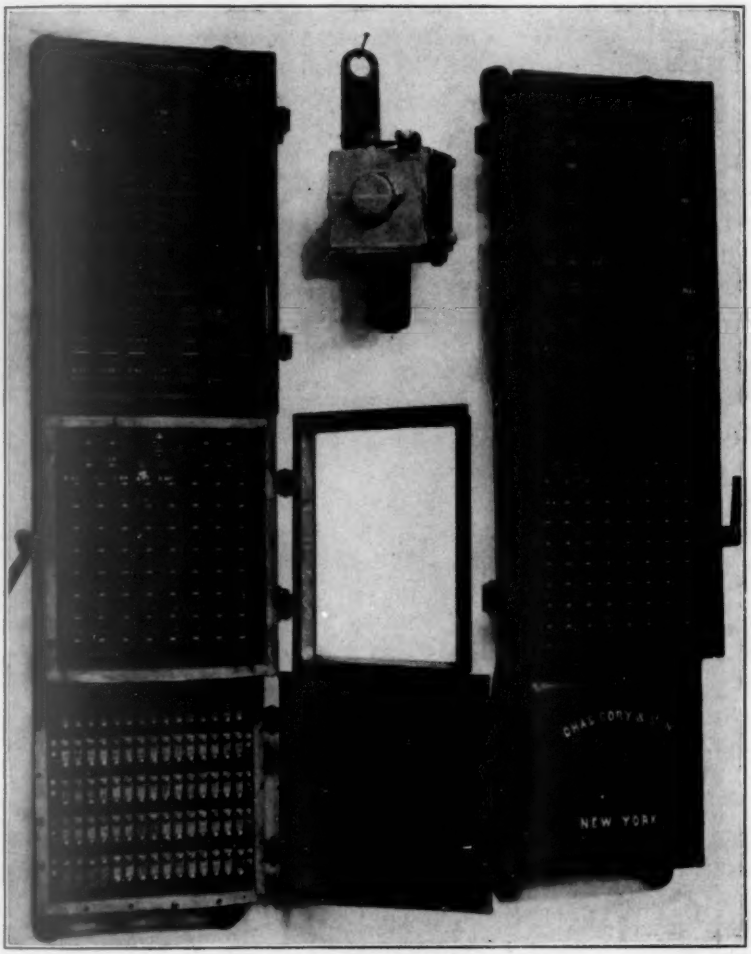
The steamboat inspection service makes the telephone a requirement on certain types of vessels. "On all steamers where the distance is more than a hundred and fifty feet between perpendiculars of pilot-house and forward part of engine room, there shall be communication by means of a telephone between the pilot-house and engine room, such telephone to be installed in lieu of a speaking tube." This condition will inevitably arise in vessels where the engines are located far astern or on vessels of unusual length. With the exception of this telephone circuit, all other telephone communication is optional and employed only for convenience. The development of the telephone for merchant vessels has not only been curtailed, but almost shattered by the falling off in construction of such vessels in this country. The memory must be strained to recall the last transatlantic steamer of American construction, and coastwise steamers for passengers and freight are few and rare. A glance at American shipping for the last two years will readily convince. The shipyards of the country for this period have been sustained mainly by the government. An exact description, therefore, of the telephone installed on passenger and freight vessels must be at least vague. Later it will be seen that this important land instrument has been adopted in the United States navy and a steady development has succeeded. This development work, like many others, has an immediate and intimate effect on the merchant marine. Illustrating this the writer installed some two years ago on a coastwise passenger steamer eight intercommunicating telephones. These instruments were relied upon to the extent of omitting the mechanical docking and steering telegraphs. They also estab-

lished convenient communication for the captain and chief engineer. At that time the navy was experimenting with what is known as the "loud-speaking" telephone (some authorities consider this a well-sounding phrase), which has now been superseded. This type of telephone was adopted for the case in hand. The system, as far as the telephones were concerned, was a common battery, three-wire circuit, other wires naturally being installed for the intercommunicating feature. The telephones for exposed places and where the noises were excessive were entirely enclosed in water-tight brass boxes. To exclude external sound as far as possible double arm receivers made flexible for convenience extended from each side of the enclosing case. The non-water-tight telephones usually installed in the staterooms had all their parts directly attached and were self-contained. The delicate parts were also encased, but mounted in a hard-wood frame. A revolving lever brought the transmitter into circuit. These telephones would in nearly every case reproduce the human voice to such intensity that it would be audible some six or seven feet away from the instrument. In other large installations of telephones on shipboard recurrence to land practice usually prevails. Switch boards for ordinary land service are installed, and either batteries, or batteries and generators, included therewith. The problems involved will be better understood in viewing the development from a naval standpoint.

As a system of convenience, just as in land practice, the ordinary call-bell with push-buttons is without a rival. As an adjunct to the voice-tube system it maintains the dignity of its importance, although on many merchant vessels its place is filled by a whistle in the voice-tube mouthpiece. Annunciators resembling those found in offices and hotels are manufactured with a drop of such design that the rolling and vibrations of the vessel will in no way affect their proper and accurate operation. For above all things a system of convenience must, as such, work consistently. Despite all the wonders of electricity and all the development by all the mighty minds, if you press a button and there is no result therefrom, you not only become an atheist, but a positive pluperfect anarchist. With push-buttons made of water-tight pattern where exposed to the weather or rough usage, with innocuous ones in the better part of the ship and with well-designed annunciators, the call-bell system not only possesses an

enviable and convenient position, but also is as indispensable to the comfort of the passengers and officers as the pleasant quarters or the agreeable cuisine.

FIG. 1.



Metallic thermostat and thermostat annunciators.

The distinction between the mechanical instruments used on naval vessels and those employed on merchant ships has been punctuated. There are three systems of such communication

that are not ordinarily fitted on the latter type of ships, but which are never omitted from battleships, namely, fire-room telegraphs, blower telegraphs, and turret-hoist telegraphs. The principles of their operation and methods of installation remain the same. Turret-hoist signals were only lately changed from electrical to mechanical, due to the sluggishness of the carbon filament incandescent lamps as compared to the increase in speed of the hoist, the latter lifting the charge from the handling-room to the gun breech in five seconds. The signals are very simple, to wit: "Hoist," "Lower." The fire-room telegraphs control the management of the fire-rooms (or boiler-rooms). For the accomplishment of this purpose their dials are accordingly designed. They read as follows: "More feed," "All right," "Less feed," "Stop firing," "Priming," "Stop," "Slow,' "Full speed," "Start auxiliary feed," "More steam." In battleships, where the design of the compartments has required that the forced-draft blowers be located at some remote place as regards the fire-room floor, the use of telegraphs was occasioned for the purpose of producing more or less draft as the conditions might demand. The regular fire-room telegraph has been requisitioned for this object with naturally its dial readings changed to those which would follow from the application. The signals indicate to the operators at the blowers to increase or decrease the speed of the motors. Electric motors are now the prime movers for these auxiliaries instead of steam engines. Mechanical gongs and jingle bells for the operation of the anchor windlass engine, ash hoists, and on the transfer platforms of the turrets complete the signals that are not either electrical or electro-mechanical, if the latter classification include the voice-tube system.

To the questions of pure electrical engineering there is augmented on naval vessels the important factor of military efficiency. Expanded this means that all apparatus must be so designed that it will be accurate and trustworthy under any and all conditions of war. That the material and instruments must withstand shocks from within when the vessel is offering her defense in action and will maintain stolidly the hot shells of her enemy in return. Development on military lines is perforce gradual when the basis of the movement revolves around the theory of battle. War is by good fortune quite rare in these "piping times of peace." But as the wise nation must prepare for war in

time of peace, the development work on military lines can advance only by the observation of past naval engagements and sensible deductions from them. It might be generally stated that these interior communications divide themselves into those which are used for the ordinary peaceful movements of the vessel and those which are useful and necessary in time of actual conflict. For the purpose of being continually prepared these latter signals are always employed in drill and gun practice. With such accumulation of systems it does occur that certain ones make themselves factors in both cases to such a degree that it would appear that no taxonomy could be assumed. Such systems as the call bells, telephones and voice-tubes illustrate this clearly. These systems are just as important in battle service as in peaceful cruising. The following arrangement, though open to question, will be adopted for the purpose of this discussion:

Systems employed for both battle and cruising: *

a. Engine revolution telegraph.
b. Engine shaft revolution indicator.
c. Steering telegraph.
d. Helm angle indicator.
e. Fire-room timing.
f. Call bell.
  Exposed.
  Unexposed.
g. Voice tube.
h. Telephone.
  General.
  Engine and fire-room.
  Bridge and engine room.
  Battle.

Systems employed during cruising only:

a. Fire alarm.
b. General alarm gong.
c. Anchor handling and boat hour gong.
d. Warning signal.
e. Fuel oil tank indicator.

* It must be held in mind that these systems are available under all conditions. The writer adopts this classification merely for convenience.

Systems employed during battle only:

a. Broadside ammunition hoist.
b. Broadside salvo-firing.
c. Turret salvo-firing.
d. Cease firing.
e. Gun firing.
f. Torpedo firing.
g. Gyro indicating.
h Range and deflection.
i. Local turret gun firing indicator.
j. Turret danger zone.

It will be noted that of the systems enumerated nearly 50 per cent. are devoted to the control of the guns. Later it will be brought out that besides these special systems the telephone and voice-tubes are important factors to-day in the naval war drama.

At the present time electric engine revolution telegraphs, steering telegraphs and helm angle indicators are designed after the "lamp pattern" type of instrument. They are identical in their method of wiring and general design, so that a description of one will suffice for all. Engine revolution telegraphs are designed for the purpose of increasing or decreasing the speed of the vessel during squadron formation.* The vessel being under orders for maintaining standard speed, this being indicated by the mechanical telegraphs, one, two, three, or four more revolutions, will be signalled by this electrical telegraph. On the bridge the transmitter of the pedestal type, by the operation of moving a handle around the circumference of the head, rings a bell and lights a lamp in the engine room, which latter signal requires the moving of a similar handle on the engine-room indicator to the revolutions desired. This done, the lamp in the transmitter is lighted, giving assurance that the signal has been received and the operation accomplished. The contact-maker in the transmitter or indicator consists simply of carbons which are revolved by the handle across insulated copper segments to complete the lamp circuits. The older type of instrument required the rapid

* The adoption of steam turbines for propelling purposes now requires an entirely new design of instrument, due to the lack of close control of turbine speeds and increase in propellor revolutions. Therefore these instruments are designed to transmit any number of revolutions. The proposed type is similar to the familiar "carriage call" device.

FIG. 2.

Engine revolution transmitter. Electric lamp type.

FIG. 3.

Engine revolution transmitter. Electric lamp type with dial removed.

movement of the handle of the transmitter or indicator for the purpose of operating a magneto-generator to ring the bell, but the latest design provides bells designed for 125 volts, the standard used in the United States navy.

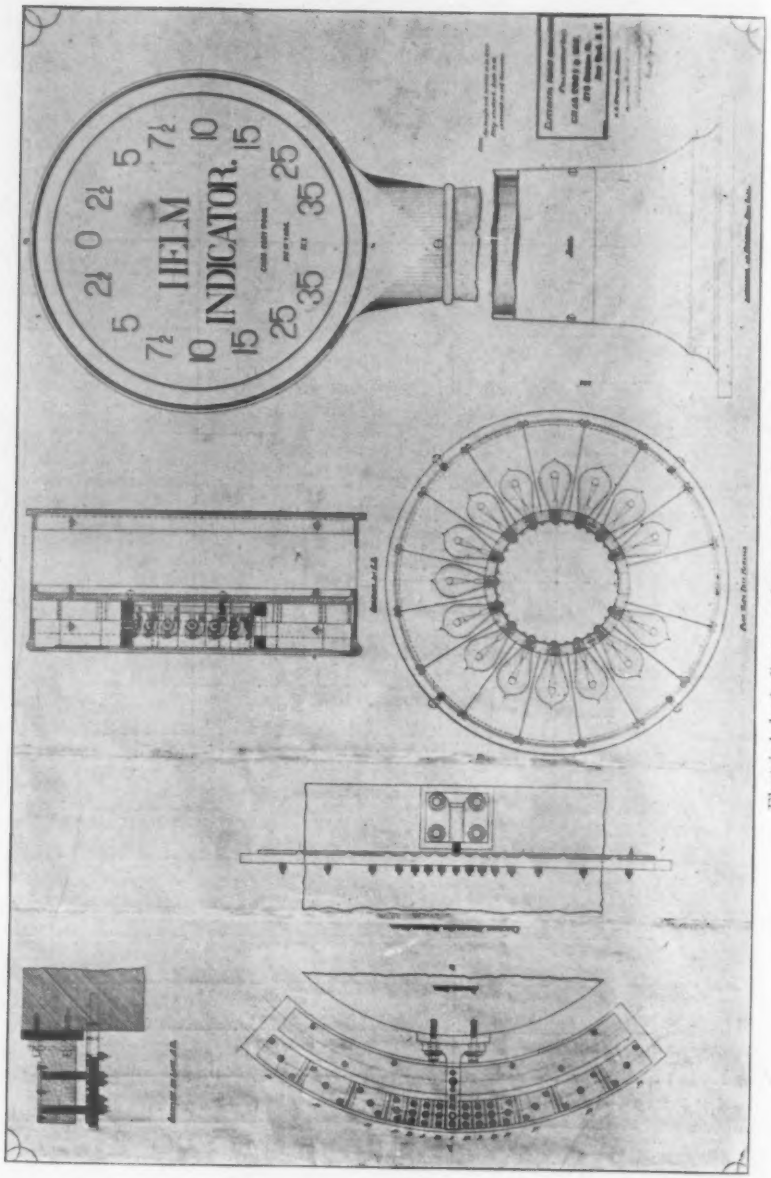


FIG. 4.

Electric helm indicator and transmitter. Lamp type.

In like manner steering telegraphs * of the pedestal and bulkhead type are installed on the bridge, in the steering-engine room, and central station for giving signals, usually in degrees, for the proper manœuvring of the vessel.

The helm indicators are built on the same lines, are located in the same places, and are for purposes of signalling the number of degrees the helm makes when the rudder has been actually moved from the midship line. The indicators are all wired in parallel with the transmitters, but are so arranged with cut-out switches that only those indicators desired may be in service. The transmitter is located near the rudder stock and the contact

FIG. 5.

Engine shaft speed indicator.

arm directly attached thereto. Carbon brushes move over insulated segments of copper, which are designed in accordance with the mechanical arc through which the rudder moves. The vital parts of these instruments are enclosed in water-tight brass cases, which carry with them sufficient protection from mechanical injury.

Engine-shaft indicators are located in the pilot-house and central station and by direct mechanical attachment to the main engine-shaft permit the direction and number of revolutions of the engine to be read at any time. The dials of the indicators now made of brass are marked "Ahead" and "Astern." Be-

* The dials of the steering telegraphs have recently been changed to read as follows: "Amid," "Course," "Steady," "Starboard," "Port," "Meet Her," "Ease Helm," "5 Degrees," "10 Degrees," "15 Degrees," "Standard," "Hard Over."

tween these indicators rests a pivoted arrow actuated by a double set of magnets. As these magnets are put into circuit by the transmitter they move the arrow intermittently either to the right or left, marking thus each revolution of the shaft. With a stop watch the revolutions per minute may be easily and quickly noted. The shaft-speed transmitter has received very beneficial development in the past three years. From a device, which was not only very careless in its operation, but so overworked that its parts could not stand the continued strains, there emerges an instrument thoroughly reliable and not apt to lead to the engineer's increase of vocabulary. A worm-band is securely fastened to the main shaft, into which engages a worm-wheel. This latter by an extension shaft carries and operates the electrical contacts fixed on a drum. The worm-wheel revolves once for every ten revolutions of the main shaft, thereby lessening greatly all strains. The electrical contacts can be so arranged that they mark every revolution or any proportional number. The brushes, as in the other instruments, are of carbon.*

While great improvements are made in important large systems and apparatus, it is remarkable how long crude methods remain by which the desired results are attained. Contractors for battleships are required to demonstrate that the vessel will under certain stipulated conditions acquire and maintain a guaranteed speed. It can be plainly seen that the greatest requisite to meet this condition is sufficient and constant steam pressure. Passing from this stage the smooth and regular firing of the boilers becomes the point of vital interest for the accomplishment of the result, of interest not only to the builder but as well to the owner, for he also desires that the vessel be capable at all times of producing this guaranteed speed. Until recently the method employed was by word of mouth from the engine room with men calling off the time intervals from watches, these latter posted in each fire-room. To-day these signals are automatically and chronologically regulated and transmitted from the engine room to each fire-room. The transmitter consists essentially of a small motor driving through gear and two steel discs a drum containing on its periphery contact segments. Between the steel discs is placed a raw-hide pinion movable from the circumference of the

* This instrument is now to be superseded by a direct reading instrument —designed to indicate continuously any and all speed changes.

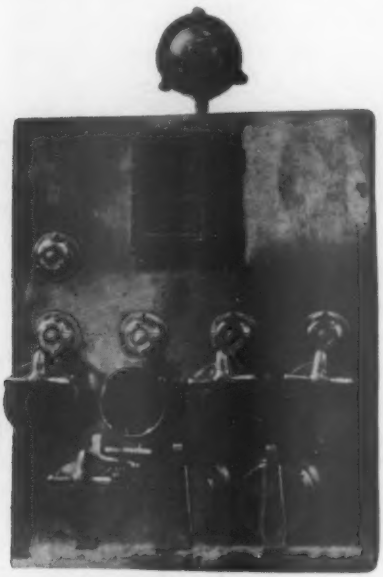
disc to the centre. By varying the position of this pinion the revolutions of the contact drum are controlled. A graduated pointer on the exterior of the water-tight case permits the interval of firing from twenty seconds to ten minutes. This transmitter is connected by a cable of wires to the various indicators, one usually in each fire-room. These are designed to produce both aural and visual signals, *i.e.*, a large gong and incandescent lamp. They are about 14 inches in diameter, marked with raised letters "Fire Furnace No. —" above a small opening. In the interior a brass dial cut with the figures of the furnace numbers is revolved by a ratchet movement accomplished by magnets, as they are energized by the closing of the circuits controlled by the transmitter. In this way the number appears in the opening of the indicator simultaneously with the sounding of the gong. This is the simplest system that has found favor at the present time, although there are others which, being more complicated, still provide the same results.

Employed for use in the officers' quarters the call-bell system is one entirely of comfort and convenience. The various pantries and orderlies are supplied with annunciators connected with push-buttons located in the officers' state-rooms and offices. This system divides into groups corresponding to the military grouping or rank of the officers. There are calls for the admiral and captain, ward-room calls, junior officers' calls and warrant officers' calls. Since the general change in type of installation from moulding to conduit, the design of all annunciators, push-buttons, and accompanying appliances take the prevailing characteristics of water-tightness. The annunciator drops are carefully constructed on the gravity principle with sufficient safety to protect against false signals due to vibrations or gun shock. The call-bell system, which operates in conjunction with the voice-tube system, is sharply divided for military safety into exposed and unexposed calls. In such manner the circuits that may be required in the opening of an engagement, and thereby made useless when the conflict rises to its height, will not make unavailable those circuits which in the interior of the vessel are still of vital necessity. It is the practice to duplicate the call, that is, that a push-button and bell are required at both ends of the voice-tube. As may be surmised, it often transpires that many voice-tubes with their calling apparatus meet in one compartment. This leads to

a system of stations located at important points throughout the vessel. At these stations it is convenient to group all the voice-tube mouthpieces, push-buttons, bells, or buzzers and annunciator on a brass panel. This preserves space and produces an excellent installation. The push-buttons are all carefully labelled so that communication can be quickly and, with the aid of the annunciator, intelligibly established.

It may be written without fear of contradiction that voice-tubes parallel every important system of interior communication.

FIG. 6.



Call-bell and voice-tube panel.

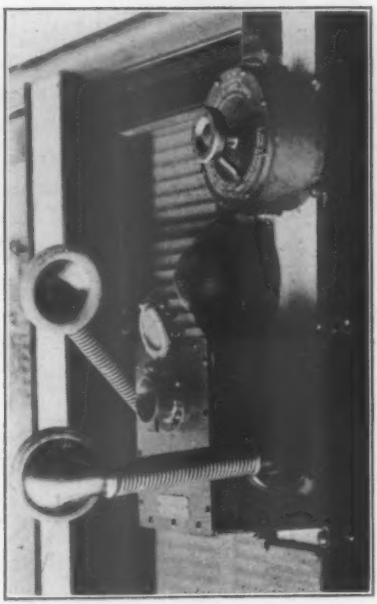
They are seamless hard-drawn brass tubes varying in external diameter from 1½ to 4 inches. Tubes vary in thickness for the purpose of mechanical strength, those which are led in straight runs No. 20 B.W.G. and those for bends and where subject to mechanical strains No. 14 B.W.G. Where tubes connect two terminal points by a direct path, or of a large diameter, so that they may be utilized for shouting-tubes, or when they are employed for gun-firing control, they are not provided with calling arrangements as above explained. Certain of these tubes are

fitted with whistle mouthpieces in lieu of the bell and push-button. Mouthpieces differ in design for nearly every condition of use, and only a detailed description could fairly represent and explain them. Indeed, as new conditions arise, or more efficient methods present themselves, the mouthpieces are immediately attacked and the old types ordered into exile. Between compartments that are water-tight special mouthpieces of water-tight design are installed; between non-water-tight compartments, or non-water-tight and water-tight, a simple covered or open type. For shouting-tubes, usually 3 inches or 4 inches in diameter, a design of the pattern of a megaphone is preferred. In the boiler rooms, where the forced draft occasions a disturbing pressure, the design provided is that of a diaphragm in the mouthpiece, which can be only affected by the human voice. The tubes used solely for the control of gun-fire are arranged so that a long flexible tube can be plugged into the permanent mouthpiece. This flexible tube ends in a headgear containing in some conditions only two ear-pieces and in others the addition of a mouthpiece. This design permits the men at the guns to have the freedom of their hands, at the same time receiving direct aural orders from the officer in charge of the guns. It will be observed later how this system has taken its cue from the present adaptation of the telephone for this like duty. To obtain the greatest good from the voice-tube system extreme care is observed in all requirements of its installation. Those points of inefficiency which were indicated in the description of this system for merchant vessels are overcome as far as possible in naval vessels. The navigating bridge is in most recent designs entirely enclosed, and the voice-tube connecting the engine room, irrespective of other considerations, is led in the most direct line to the engine-starting platform. Machinery noises and vibrations are not, to be sure, entirely overcome, but every effort is exerted to accomplish the intelligent transmission of the voice. The criterion at the present moment must appear in the abundant and important uses that our navy finds for their increased employment.

Retrospectively the development of the telephone on battleships is remarkable. As late as 1903 a few telephones of the commercial type were installed merely as a matter of experiment. They consisted simply of a box telephone with transmitter and receiver on a hook such as were prevalent in office buildings, en-

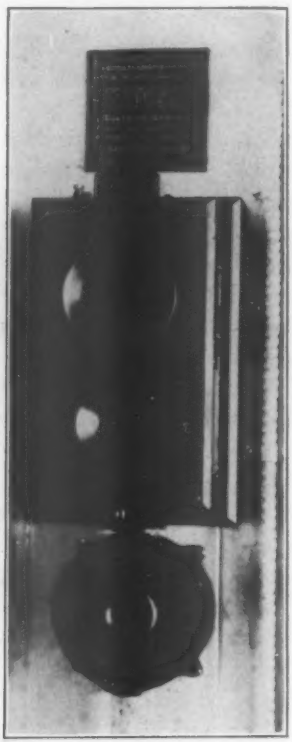
cased in brass for protection in exposed places. Their use was purely a matter of convenience, doubtless little reliance being ascribed to them. The patents covered by the Bell Telephone Company nearing proscription, other parties began experiments for a suitable telephone for marine purposes. The question had

FIG. 7.



Water-tight type "loud-speaking" telephone.

FIG. 8.



Non-water-tight type "loud-speaking" telephone.

not been largely discussed nor experimentation fruitful. However, one observation, that of noises within the vessel, conspired to the design of a telephone which would by its volume, or intensification of the human voice, and by the exclusion of external noises compass the solution of the problem. This type of telephone was designed, as had been its predecessors, to mount on bulkheads. All portable receivers were discarded and the instru-

ment performed its functions with as little human aid as possible. Double receivers to exclude sounds other than the established circuit would permit were an important adjunct to the water-tight type. The non-water-tight type, as explained previously, could speak so audibly that it was unnecessary to place the ear to the receiver or to hold the lips near to the transmitter. The receivers were wound for a low resistance, so that the energy necessary was that of a few batteries, usually five. These telephones supplied communication for the general service, and were therefore, interconnected as desired by a water-tight telephone switchboard located in the central station. This telephone switchboard is interesting. It is still employed. No cords or plugs or jacks can be found on it. This will probably surprise our telephone engineers. All the interconnections are made by small "throw-over" or "tumbler" switches. Other features of the board are recognizable, night-bell, visual drops, clearing-out drops, operator's head-set, etc. The circuits were divided up into groups of five, which for a forty-line board and the general use of the system on shipboard was found to be ample.

But to return to the telephones. It was early pointed out that though ships' noises did affect the hearing qualities, vibrations transmitted to the various bulkheads acted more to their disparagement and disuse. Coupled with the interferences of the proper hearing qualities, came the effect of the packing of the carbon granules in the transmitters. These two salient objections told upon the advantages thought to be realized in this excellently made telephone and led to the types now specified and installed. No stint of praise should be allowed to the achievement of the "loud-speaking" telephones, for in their passing they have confirmed the telephone for yet greater service—that of controlling the engines of war. So the order was issued that all telephones must be taken off of bulkheads; no more low-resistance receivers; back to the standard voltage in commercial practice and back to a simple two-wire system. From a system depending only on batteries without any intervening coils, emerges a system replete with condensers, induction coils, alternating current ringer, etc. Another step in advance breaks up the whole into four distinct divisions: A general telephone system for the convenience of the officers; a special and independent set of circuits connecting the fire-rooms and engine rooms; another special

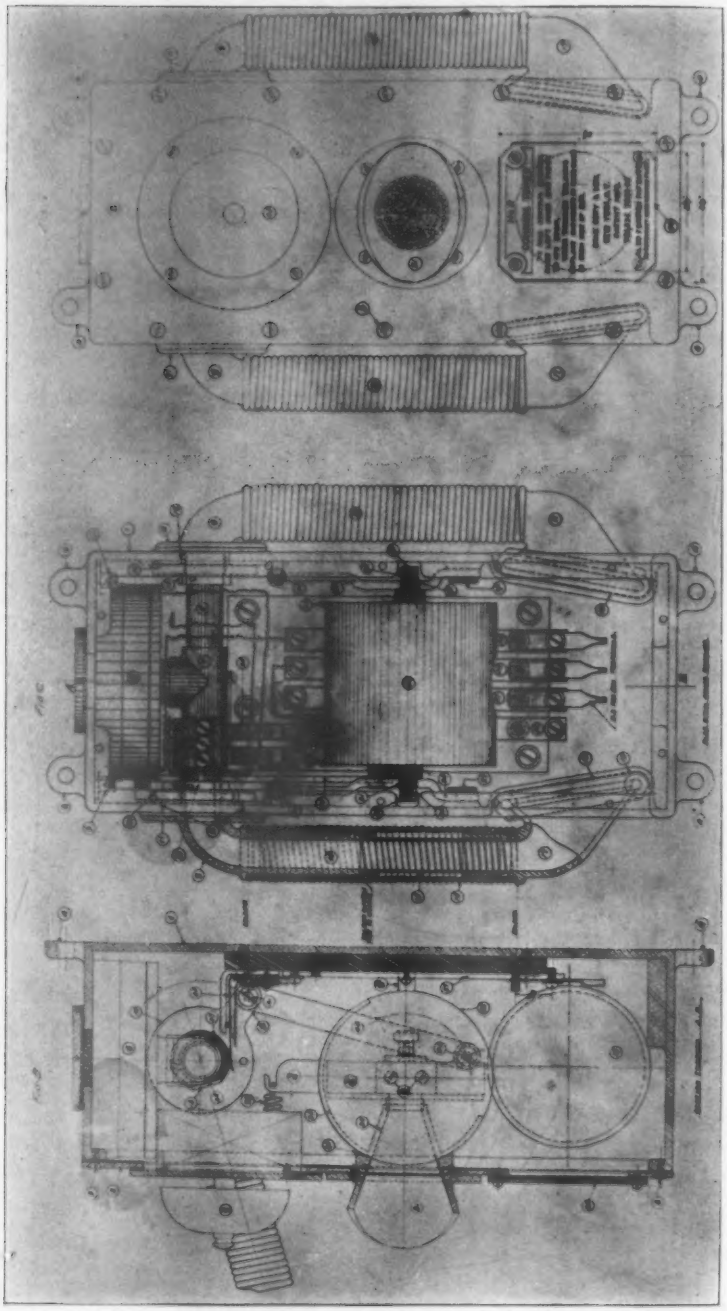


FIG. 9.

External and internal view, "loud-speaking" telephone. Water-tight type.

circuit between the engine room and the bridge; and last, but by far the mightiest, an elaborate system for the control of the guns during battle.

In the officers' state-rooms and compartments, where the telephone is not subject to exposure, the hand telephone set consisting of one transmitter and one receiver is suspended when not in use from a water-tight case which contains the condenser and bell mechanism. The act of taking the telephone down for use, or returning it thereafter, automatically operates a switch on the top of the case which establishes the circuit to the switchboard. The water-tight telephone is similar in operation, differing only in that the telephone hand-set is enclosed in a stowage box; when this is opened the circuit is established to the switchboard. The telephones connecting the fire-rooms and engine rooms are like the water-tight type used on the general telephone system with this difference, that no bells are provided. The system does not pass through the telephone switchboard, and therefore the calling apparatus is taken from the general interior communication system, consisting of direct-current bells and push-buttons. The circuits between the bridge and engine room are direct, as in the latter system, having no connection whatever with the general telephone system. The telephones are exactly the same as those installed for gun control. The live wires are brought to a terminal in a brass box, which serves as a permanent fixture wherein to stow the telephone set. A portable twin wire is led to two receivers wired in multiple arranged to fit comfortably on the head. By means of a hard-rubber plug and jack cut into the portable twin conductor a breast type of transmitter may be introduced to complete the outfit. This permits the use of the hands and produces continuous communications. The breast transmitter has a vertical adjustment of three inches, a back and forward movement of 30 degrees and a side movement of 180 degrees. Energy is supplied to all of these systems, including the battle telephones, through a transfer panel located in the central station. There is further provided for the bridge and engine telephone circuits a transfer switch, so that the exposed circuit to the bridge may be cut out in case the bridge is destroyed in action, and communication safely maintained from the central station. It would only weary the reader to describe each and every sub-division of battle telephone system unless he were deeply interested in

military questions. Such information he would hardly seek from this paper. As nearly every battleship differs as to her complement of guns, their arrangement or calibre, it is evident that a description of one particular vessel would not apply to others. Suffice it to add, therefore, that in general there will be found a separate and complete system for the guns of large size mounted in turrets; one for the secondary battery (or torpedo-defense guns); one for searchlights which are necessary for torpedo defense at night; one for torpedo firing; and one for the exclusive use of the range-officer. The utilization of these battle telephones will be more clearly appreciated when shown later in conjunction with their correlated system of fire control.

Of the systems which are not actually necessary for military operations unquestionably the fire-alarm system is the most important. Until recently metallic thermostats, acting upon the difference of the expansion of two dissimilar metals, were installed in all the coal bunkers, magazines and store-rooms; but this type has been found deficient in many ways and so has been superseded by a simple mercurial type. The circuits from the thermostats are all led to annunciators constructed like those for the call-bell system, having as an auxiliary a switch for each line in order that the bell may be cut out of circuit after an alarm has been given.

The general alarm gong system, consisting of two or three contact-makers and 30 odd 12-inch electric gongs, serves the purpose of calling the crew to drill or arms or giving an alarm in case of danger.

The purpose of anchor handling and boat hour gongs is implied in their names. The gongs are usually 8 inches in diameter and are actuated by push-buttons. The former give directions from the forecastle deck for the control of the anchor windlass engine; the latter provide a call notice to the officers' quarters that the shore-cutter is ready to depart.

A warning is provided for the closing of all water-tight doors in cases of collision. The necessity here is for a sound that will be distinguishable from the noises of machinery. The first means devised and one long used was that of an electric magnet compressing enough air and allowing it to escape through a shrill whistle. The sound produced greatly resembled the familiar chirp of the cricket. This has now been superseded by what is

known as the electric "howler." A magnet actuates a hammer against a tight pigskin diaphragm, the noise being intensified by a horn such as seen on automobiles. The sound is not as shrill as the whistles, but is sufficiently differentiated from the ship noises to be entirely satisfactory.

In vessels carrying oil for fuel it becomes evident that some indication must be given as to the height of the oil in the tanks when filling same. An ordinary float in the tank provides the switch for closing the necessary circuits. Indications are shown on an annunciator of the ordinary type.

It is essential among the systems purely for the control of the guns that primarily provision be made to quickly handle the ammunition. For the large turret guns it has been explained that mechanical signals are employed. In the case of the secondary battery, although voice-tubes allow verbal signals to be transmitted, there has lately been installed a system designated as broadside ammunition hoist signals. The indicators consist of a simple brass water-tight case with round white discs properly marked and illuminated by 5-candle power incandescent lamps. The markings provide for signals to hoist, lower and stop as well as to determine the kind of ammunition desired. Transmitters consist of several standard switches mounted in one case and properly designated. As a check a similar indicator is installed at the loading end of the hoist and the lamps wired in series, the transmitter with indicator being located at the upper or receiving end of the hoist.

In order that the turret guns and secondary battery may fire a broadside simultaneously, systems of bells, buzzers and contact makers have been designed. These systems have been nominated respectively for the turret guns—turret salvo-firing, and for the smaller guns—broadside salvo-firing. Small 3-inch electric bells are permanently installed in and about the guns so as to be distinctly audible; they give the order to "stand-by." Portable buzzers strapped to the chests of the gunners are operated by push-buttons and give the signal to "Fire." The contact makers and push-buttons are located at the two principal fighting-tops, the captain's battle station and the sub-stations. The point interesting to note in this system is that of strapping the buzzers to the gunners. This is done in order that there can be no mistake in the interpretation of the signals, for though it may not be

audible, the vibrations of the buzzer will be communicated to the body.

The cease-firing system is identical to the general alarm system. The diameter of the gongs for this system is made 10 inches instead of 12 inches. On some battleships in order to better differentiate the sound one system will have vibratory gongs, the other single-stroke. This system provides signals to commence and cease firing and pervades the entire vessels. Thus it is a general gun signal.

At the present writing the actual electric firing of the guns from the vessel's electric plant has never been required. The guns are provided with a local battery system and the consideration to-day is not only to retain this means, but also to provide a similar system taken from the vessel's permanent installation. Special motor generators are to be designed so that only the requisite voltage and current will be delivered to the guns. Switches of a portable type, receptacles for connection at the guns and other necessary appliances will be furnished. No details have yet been considered, and it is problematical whether such a system will not in the end find much objection in the opinion of those vitally concerned.

Morale in warfare is an important factor. The enemy must be more or less affected by what he estimates as the fighting strength of his opponent, or what the latter may hold in reserve as reinforcement. So there are retained in our large battleships at least two torpedo tubes. From stations located on the superstructure deck the firing of the torpedos is not only directed but actually accomplished. Firing keys, not unlike telegraph keys, are located at these firing stations in conjunction with signals that permit no complication before the firing keys are actuated.

To give the necessary directive action to the torpedoes a system of telegraph indicators and transmitters of the lamp pattern, as described under the head of electric engine revolution and electric steering telegraphs, is installed—one transmitter at each torpedo firing station with indicators at each torpedo tube. These transmitters indicate at the torpedo tubes the number of degrees from zero centre reading to 90 degrees port and starboard. This system bears the natural title of the gyro-indicator system, as by this means the torpedo gyroscope is so adjusted.

Of all essential matters in battleship design that of properly

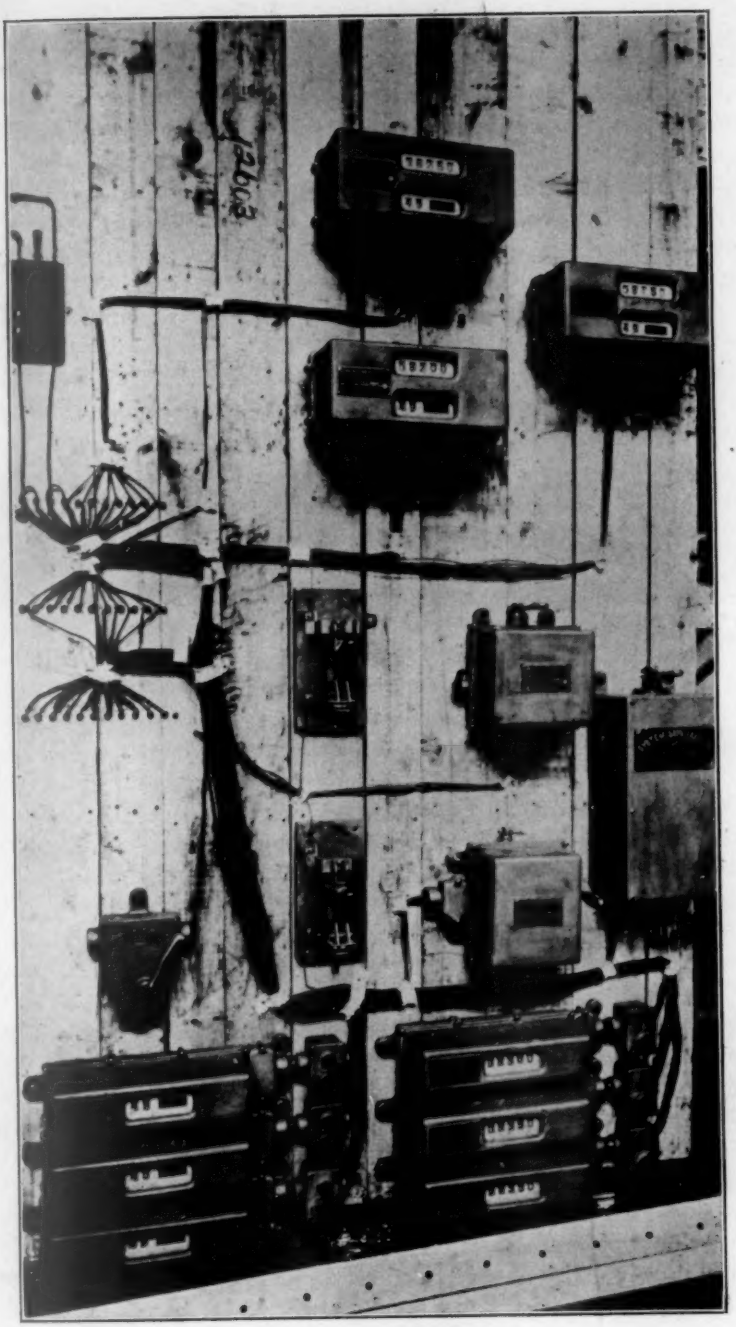
controlling the fire of the guns is without question the most important. A battleship is primarily a fighting machine, and therefore the necessity of so controlling the gun fire as to obtain the greatest battle efficiency. This subject of fire-control has called forth every consideration by the naval authorities, and investigation, experiment, and money have not been spared in providing the most reliable systems suggested. Every idea that was worthy a passing notice has been given due trial and the liberal spirit of the government to-day would gladly respond to any suggestions whereby greater improvements would result. To clearly understand the arrangements now provided on the latest battleship designs some reference must be made to the arrangement of compartments and the disposition of the guns. The design of recent battleships has been rightly dubbed the " all big gun " type. Our most powerful battleships, those of over 21,000 tons displacement, carry five turrets, containing two 12-inch guns in each turret. Two are located forward, one raised slightly above the other, and three aft, two on the same level and one slightly raised above them. The 5-inch guns used for defense against the attacks of torpedo boats are distributed at important points on the gun deck. The range, deflection, and battle orders for these guns are communicated solely by telephones, as referred to in the description of the telephone system. Not only are the 12-inch turret guns supplied with telephones for this purpose, but also with special instruments for visually presenting the range, deflection, and battle orders continuously before the sight setters and gun trainers.

The orders all emanate from what are called sub-stations, compartments well below the protective deck and water-line, sheltered in every possible way from hostile shell. The range-finding instruments are located in lofty towers, one forward and one aft, with their respective " spotters " and range officers. The spotters, watching each shot as it falls and gauging the range and deflection, communicate directly with the sub-stations by means of the telephone. The range and deflection transmitters in the sub-stations are immediately called into operation and in turn send forth to each gun the proper order. The problem contains another factor. In naval warfare both parties to the conflict are in motion, and by virtue thereof the range is constantly varying. For this condition there is provided in the sub-stations a range

clock carrying a rate of change disc, by means of which the rate of change of range may at all times be marked. This range clock has a maximum reading of 14,000 yards. When the shot-spotter reports from the fire-control tower, the rate of change of range is set on the clock. The clock continues then to mark off regular ranges which, through the proper official, are then communicated by the range transmitters to the guns. Deflections are noted by the same shot-spotter and in the same way transmitted through the sub-station to the guns. Deflections are measured in yards up to a maximum of 100. Formerly zero was arbitrarily taken at the centre, which required the further designation of right or left deflection. By assuming 50 yards as the zero deflection any number below 50 indicates right and any number above 50 indicates left deflection.

The cause for all this care in firing guns originates from the desideratum of "bunching" the hits. When several guns are firing particularly in range and their shots are dispersed, poor hitting ensues. Therefore such fire-control systems are important and necessary in that they maintain all the sights of the guns set alike while in the act of firing. Two systems for accomplishing this requirement have been experimented with and have shown about equal advantage and disadvantage from a practical standpoint. It is unnecessary to elaborate a description of either system, suffice it to say that one system is designed on the simple incandescent lamp principle, and the other on a system of magnets in conjunction with ratchet-motion escapements. In the former indications are produced by illuminating numbers by 5-candle power lamps; in the latter the range and deflection numbers revolve by increments of 50 yards for range and unit increments for deflection. The latter instruments, though rectangular instead of round, resemble in their movements the familiar fare registers which are seen in all trolley cars. This system provides also for the repetition of the signal after it has been conveyed to the gun at the sending station. Ready means are also provided for cutting out the instruments which may become deranged without affecting the other instruments on the system. This reply or checking feature is convincingly accomplished in the lamp-pattern design by introducing similar indicators at the sending station connected in series with the indicators at the guns. The transmitters in both systems, though the instruments are dissimi-

FIG. 10.



Assembly of fire-control instruments.

lar in outward design, are in principal merely switches for closing the desired circuits. The essential difference between the lamp-pattern and the electro-magnet systems is that the former is purely an electric contact method and the latter an electro-mechanical movement.

The vital importance which attaches to this fire-control system is shown by the regard with which it is installed. With all these instruments located behind and below armor, in the event that the fire-control towers be completely demolished, communication can be transmitted from the captain's battle station, which is a small elliptical armored compartment on the superstructure deck. If again by any chance this invulnerable citadel be destroyed, retirement to the sub-station is offered. This latter place can only be made untenable by the sinking of the vessel. When this happens the hull becomes only a hulk and the engine-of-war becomes a derelict.

The last two systems in this classification, namely, local turret gun firing indicator system and turret danger zone system, may consistently be considered together. They have been required mainly because to-day it is thought one system cannot accomplish all that is desired. And certainly a detailed investigation will convince even the most conscientious designer that a division was absolutely unavoidable. It has been stated that in the "all big gun" design the turrets are disposed, two forward, one above the other and three aft, two on the same level and one above them. With this alone in mind it becomes apparent that unless due provision is made there will occur in time of war, or target practice, exceedingly dangerous interferences, not only by the various positions of the guns, but also by the turrets which carry them. Casually the suggestion would be to guard the turrets and guns by positive mechanical blocking devices; but this is impractical inasmuch as it restricts to an alarming extent the radius of gun action, a restriction which would reduce the efficiency of the fighting qualities of the vessel to a mere show in battle. The guns have a certain radius of elevation and depression, just as the turret has a fixed radius of train on a horizontal plane. One gun or set of guns in one turret, let it be the raised turret, are set for extreme depression, while the guns in the lower turret are fixed at maximum elevation on the same degree of train. If under these conditions the raised turret guns are fired, they throw their charge with disastrous results at the lower turret guns. A

change in train of the raised or lower turret would avoid any such mishap. Here it must be understood that the turret gunners are excluded from external view, hemmed in behind 12 inches of armor. The sighting of the guns is accomplished by prismatic telescopes, which present to the sight setters the image of the object upon which they fire. Augment the many interferences which will arise by the above illustration, by the movement of one turret body into the fighting line of an adjacent turret, and the problem is not only magnified to the extremity of hopeless solution, but becomes utterly exasperating. No instruments for this system have at the present time been manufactured. Designs have been drafted in accord with models of guns and turrets prepared to illustrate the many dangerous interferences. It remains for experimentation and actual trial to demonstrate the need or practical usefulness of a system which perforce must carry with it complications proportional with the results to be obtained. Several methods have been suggested; but to the writer's knowledge only one system has found acceptance at the present time. The principle of the design is based on the desire to eliminate at least as much as possible the use of small shafting and permit the signals to be conveyed by electric currents. Yet the method must introduce the mechanical feature, because the every motion of one gun and one turret must be transmitted to each of the other turrets or guns where interferences may occur. The system comprises two sets of instruments, one set based on purely the lamp-signal system—the transmitter mechanically attached to the gun or turret, and similar, save in size and number of contacts, to the other electrical telegraphs—and the other based on a magnet floating in a circumferential group of magnet coils whose poles alternately present a north pole and then a south pole. This, producing a revolving motion in accord with a mechanically-operated contact maker atttached either to a gun or turret, reproduces the movement in another turret. The principle is here briefly stated. The details are not conclusively prepared at present; but the object of accomplishing this work by electrical methods rather than by mechanical are at least set forth. If reliability is found to be more necessary than space, weight, and inconvenience, then the mechanical system will prevail. Thus the entire success of the turret danger zone system must await the final verdict of the future.

Many times during the explanation of the above systems men-

tion has been made of the central station. This compartment is located below the protective deck and covered from danger by armor. Besides furnishing a protected station from which to guide the vessel when the upper pilot-house has been destroyed, it also gives a cover to the necessary switching mechanisms for the supply of current to the interior communication systems. From the captain's battle station, which has been already briefly alluded to, an armored tube three feet in diameter is fitted ending in the central station. This tube protects the steering gear leads as well as the important wires and cables of the essentially battle and navigating circuits. In this room will be found the steering wheel, engine mechanical telegraphs, revolution indicators, helm angle indicator, electric steering telegraph, voice-tube panel, cut-out switchboard, interior communication switchboard (controlling the supply of all circuits for these systems), telephone switchboard, telephone transfer switchboard, general alarm gong contact maker, and warning signal contact maker. Two dynamotors for the energy necessary for the general systems of interior communication are a part of this equipment, but due to their noisy character are debarred from the silent communion with their fellows. This control station is lined on all sides with sound-proofing material, that there may be no interruptions to the service occasioned by the ship machinery. The motor generators for the supply of proper voltages, with alternating and direct current to the telephone system, are located without the central station for the same reasons. The dynamotors for the general communicating circuits are wound to transform the standard voltage of 125 volts into three voltages, 6.6, 13.3 and 19.9 volts. Motor generators in duplicate for the telephone system consist of a motor wound for 125 volts; a direct current generator transforming to a normal voltage of 16 with rheostatic control from 12 to 20 volts, mounted on the same shaft, and an alternating current generator producing 80 volts at 16 cycles, mounted on the same bed plate. These motor generators are controlled by the telephone transfer switchboard and the dynamotors are controlled by the interior communication switchboard. This latter switchboard is interesting for the amount of control it provides crowded in so small an area. It is furnished with many sets of bus-bars to accommodate the differences in potential characteristics of the various systems. It supplies 125, 6.6, 13.3, 19.9

volt bus-bars as well as a special set of bus-bars for the batteries which are connected to supply 6.6, 13.3 and 19.9 volts. Adjacent to the central station and made sound proof in like manner are found the sub-stations for fire-control. The two sub-stations permit of duplicate operation of the fire-control, that is to say, that the control of all the turret guns can be accomplished from one sub-station or divided between them. Sub-stations are provided to agree with the number of batteries. A change is now contemplated in this arrangement of compartments whereby there will be secured a further structural division, allowing a special compartment to interior communication apparatus. This arrangement will separate and make distinct the steering compartment, the communicating or central station and that reserved especially for the control of the gunfire.

Although briefly described the extensiveness of these systems goes far to prove their importance and necessity. Embracing as they do every possible need of the navigator, the engineer, the gunner, the passenger and the crew they metaphorically typify the human nervous system with all its sensitiveness and delicacy. As the human is debilitated by some injury or shock to his nerves, in like manner does the vessel suffer from an interruption to its interior signals. Following this simile to even a greater degree, man has ingeniously provided the vessel with means of premonition like unto the intuition or fear of approaching danger which man himself possesses. These advantages have transpired through man's experience, study, and persevering interest in the making of vessels secure in the carriage of human life and cargo. Not one iota should be spared from the praise of man's achievement as shown in the advantages to the English-speaking races of the two transatlantic fast mail steamers "Lusitania" and "Mauretania." In diminishing the time of travel between our shores and that of the Fatherland they have advanced the nadir of world civilization.

No attempt has been made to discuss in this paper any practice other than that of our own country. A comparison of the practice of other nations would be interesting, but would extend beyond the prescribed intention of this treatment. It is obvious to those who are well acquainted with American characteristics that in all paths that lead to progress and advancement in science, art, and civilization our countrymen will be found in the vanguard.

FRANKLIN INSTITUTE

EARTHQUAKES IN THE LIGHT OF THE NEW SEISMOLOGY.

BY

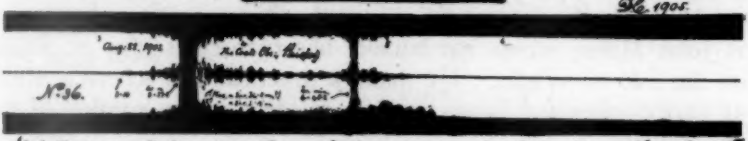
PROFESSOR OSCAR C. S. CARTER.

SEISMOLOGY is a comparatively new science; it was not until about fifty years ago that we began to study it scientifically. Alexis Perrey, a Frenchman, devoted his lifetime to the study of earthquakes, and from 1844 to 1871 compiled a comprehensive earthquake catalogue for the entire globe. This was issued in parts, and is a mine of information which has been drawn upon by workers in the subject ever since. Perrey recorded about 18,000 earthquakes in thirty years. Mr. Mallet, of Dublin, in his report on the Neapolitan earthquake which took place in 1857, was among the first to introduce true scientific method in the study. He introduced new methods of observation and took the subject from the realms of speculation, where it had previously been, and showed that it could be studied in a scientific way.

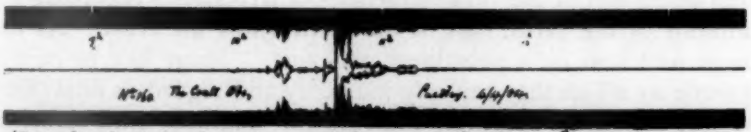
It can be seen from an inspection of Perrey's catalogue that a neglect of the study of seismology was surely not due to a want of material. It has been truly said that not an hour of the day passes but that an earthquake takes place in some part of the earth's crust. The neglect of the study of seismology may be due to the difficulty and obscurity of the subject, and the fact that man's first impulse is his safety, and he is not in a frame of mind conducive to scientific observation when this observation would be of value. The astronomer in his observatory has the heavenly bodies under his inspection night after night, so that he has named and even classified the mountains and volcanoes of the moon. The chemist can analyze in his laboratory complex compounds, minerals and rocks. The physicist can make his delicate measurements of objects he has before him. The geologist, however, when he studies earthquakes, has to deal with something very fleeting, which is generally studied by its after effects. The shock may start in a far-distant country, 3000 miles

The Coats Observatory, Paisley.

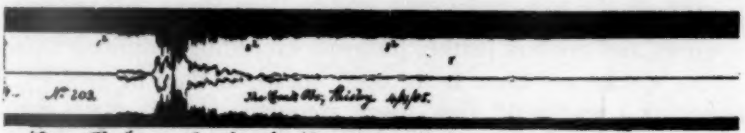
Notable Earthquakes recorded by the Milne Seismograph.



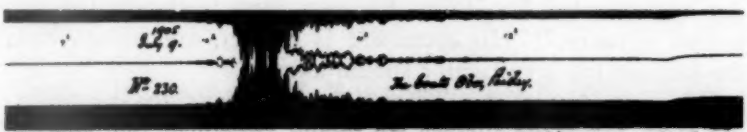
No. 36. Centre near Kashgar, Asia. Five weeks before report reached India. Felt sensibly in India.



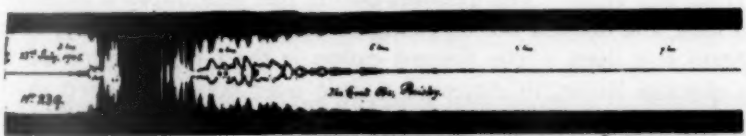
No. 160. Gelemiche, Turkey. Copy of record sent, by request, to Prof. Pernter, Vienna.



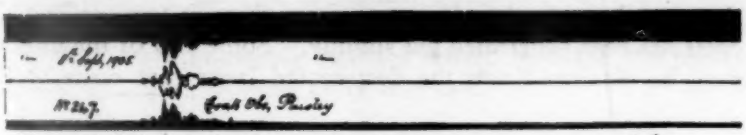
No. 202. The Indian Earthquake. Centre near Kashmir.



No. 230. Supposed origin near Kashgar. No definite news received. Possibly confused with others.



No. 234. Irkutsk, South Central Siberia. Greatest intensity of all recorded in Paisley.



No. 247. The Italian Earthquake. Another of great severity, same region, a week later.

From originals furnished by Prof. John Milne, Shide, Isle of Wight.

or more from the observatory, and, even were the observer present on the ground, the origin or centrum of the shock may often be hidden from view, some times several miles below the surface. The wonder is not that so little but that so much has been accomplished.

Probably the foremost living authority on seismic phenomena is John Milne, whose earthquake observatory is now at Shide, on the Isle of Wight. He made a practical and scientific study of earthquakes for Japan while a resident in the employ of the government.

The subject of earthquakes cannot be understood without a full discussion of the various theories or hypotheses regarding the interior of the earth, that is, the earth below the crust. As has been well said by a prominent geologist, "Many like to have a theory on which they can rely implicitly and regard as final; they dislike to sum up evidence, and suspend judgment until sufficient evidence is collected. This is a habit of mind which should be discouraged, for it deludes one into the belief that he knows the subject when he has only acquired some one's opinions and dogmas, and renders further progress exceedingly difficult to him. In no science are there more open questions than in geology, in none are changes of view more frequent, and in none, consequently, is it more important to emphasize the distinction between fact and inference, between observation and hypothesis. An open-minded hospitality for new facts is essential to intellectual advance." His statement is correct, and shows clearly the attitude the investigator should assume.

When we discuss the different theories about the condition of the earth below the surface we should remember that the study of the interior is at best a very obscure subject, being hidden from our view. The greatest boring has penetrated a little over a mile, the deepest boring being at Schladebach, Germany, about 6000 feet deep. The deepest cañon is the Grand Cañon of the Colorado River, in Arizona, a little over 6000 feet deep in the deepest part. The deepest mine in the United States is the Tamarack, in the Lake Superior copper region, where a vertical shaft was sunk a mile deep. The deepest artesian well is less than a mile in depth. It is seen from these statements that the crust has been penetrated but slightly. Some idea of the interior may be obtained from the deep-seated lavas that come to the

surface. Notwithstanding the obscurity of the subject, facts are accumulating year by year, so that it is now fairly certain which view is correct, or at least which views can be discarded.

Most of the theories about the earth can be found in "History of Geology and Paleontology" by Karl Von Zittel, and in our standard geologies, and are presented in the order in which they have been taught.

FIRST THEORY.

The first theory about the earth, and the oldest one, which is being rapidly discarded, is that the earth has a thin crust, below which is an interior of melted rock or lava. This is known as the thin crust theory, because it supposes a crust of from 20 to 30 miles thickness. As the diameter of the earth is about 8000 miles, this would make a very thin crust.

Astronomers and physicists objected to this view saying the earth behaved like a solid rigid body in space and not like a molten mass. They also pointed out that the moon exerts an attractive force on the earth and waters that cover the earth, and in Mid-Pacific a tidal wave from three to four feet high is raised, which seeks to follow the moon in its revolution. If the earth had a crust but 20 miles thick, which in its early history was much thinner, the attractive forces of the sun and moon would have buckled up its surface in the form of land waves. "It is said that Lord Kelvin demonstrated mathematically that a crust or shell of solid steel 500 kilometers (312 miles) thick would yield under the enormous pull of the sun and moon as if it were India rubber." If this is correct, it is evident that if the earth had a crust but 20 miles thick and a molten interior, the combined pull of the sun and moon would buckle up the crust in land waves, and this would take place if the crust were many miles thicker.

SECOND THEORY.

The second theory is that the earth is solid throughout and rigid as a ball of steel. This theory is held by some astronomers and physicists, who object to the thin crust theory and hold that the earth behaves as a solid body in space. This theory harmonizes with the fact that earthquake shocks or waves are transmitted from the antipodes through the solid elastic interior of the earth. This interesting fact was proved by Milne and others and will be explained more fully later on.

It is said the second theory was held by Lord Kelvin. Volcanoes, hot springs, and other thermal phenomena are not so readily explained by this theory as by the succeeding theories. According to this view, if the earth were ever in a molten condition it has cooled sufficiently to become solid.

THIRD THEORY.

The third theory is that the earth is practically solid, but beneath the crust are vast areas or patches of molten rock. In other words, there is a fused layer between the crust and the solid interior. This view was supposed to meet the objections of the astronomer and explain for the geologist the phenomena of volcanoes, but earthquake waves could never travel from the antipodes through the solid interior, and pass through two fused layers of rock on opposite sides of the earth. The waves would be destroyed. They require an elastic medium for their passage. When this theory was first advanced geologists used it to explain the fact that a girdle or belt of volcanoes encircles the earth. Beginning with Kamchatka on the north, Japan, Philippines, Borneo, Java, Sumatra, Antarctic regions, Australia, New Zealand, are volcanic. The islands off the west coast of Africa, Canaries, Cape Verde, St. Helena, etc., are volcanic. Iceland to the north is volcanic. Beginning with Terra del Fuego on the south, the entire western coast of South America is volcanic; so is Central America, Mexico, California, Oregon, Washington, Alaska, Aleutian Islands, back to the starting point Kamchatka. This is only a partial list, as there are other belts or lines of volcanoes.

FOURTH THEORY.

The fourth theory is probably the correct one, and is that the earth is solid on account of the enormous pressure of the rocks. It is hot enough below the surface to melt rocks, but on account of the enormous pressure the material is pressed solid. Whenever an enormous fissure is formed reaching to great depths, the pressure is relieved, the rock becomes molten and the lava reaches the surface, forming a volcano. In the geological past fissure flows over the surface were formed. Earthquake waves transmitted through the earth below the crust can be explained by this view, because, notwithstanding the great heat of the rocks, they are solid and elastic and will transmit waves.

In connection with this fourth theory it may be well to quote Milne to make clear why the metals and rocks are not molten or even gaseous on account of the intense heat in the interior of the earth. Milne states: "At a depth of 200 miles the pressure would amount to about 600 tons to the square inch, probably enough to squeeze the molten rock and metal back into a solid state. At any rate a depth must soon be reached where the pressure is great enough to effect that result.

"You know the general law that heat expands and cold contracts. Well, there are strong reasons for believing that most metals and rocks can be prevented from melting under heat, if you prevent them from expanding. Or if you have a quantity of molten metal, which has already expanded in melting, you can bring it back to the solid state by great pressure, just as you can solidify liquid air by putting it under great pressure.

"The interior of the earth, though potentially liquid, is actually solid and extremely dense. It would immediately become liquid if the pressure were removed. It is hot enough to become liquid, but by the laws of matter cannot do so without expanding, and it cannot expand so long as it is squeezed down under the great weight upon it.

"You must understand that the earth, originally liquid, became solid under two influences. It began to solidify at the surface by cooling, the crust growing thicker and thicker, and it began to solidify at the centre by pressure, the core growing larger and larger. This double phenomenon of solidifying continued until a solid outer shell and a solid inner core came closer together in what may be called the critical region of the earth, a region that feeds lava to volcanoes."

HEATED INTERIOR OF THE EARTH.

Observations made in deep mines and artesian wells show that it gets about one degree hotter for about every 50 feet of descent. This increase is not regular, probably because different rocks conduct heat differently. In England the increase is one degree for 30 feet and one degree hotter for 90 feet, but all over the globe where observations have been made the average is about one degree hotter for about 50 feet.

There is one remarkable exception to this rule in the deep copper mines near Lake Superior, where the increase is but one

degree hotter for about 200 feet. Probably the ice-cold waters of Lake Superior, which are near the mine, conduct the heat away from the mines. These waters are too cold for bathing in summer.

According to the average law of increase, the rise in temperature is: 1 degree for 50 feet; 100 degrees for 5000 feet or about 1 mile (5280 feet); 3000 degrees for 30 miles.

On the surface at much less temperature than 3000 degrees silver, copper, and wrought iron can be poured from a ladle, gold vaporizes, and platinum melts. A piece of granite melts and can be poured from a ladle like so much molten glass. But under a pressure of 30 miles of rock the fusing point would rise and it would require a higher temperature to melt granite.

The views of Prof. Milne, the noted seismologist, about the increase of temperature seem to be sound. He says we do not know much about temperatures of over 3000 degrees, and that all surface rocks would melt there. He also says: "Go down 40 miles and you get a temperature of 4000 degrees; at 50 miles a temperature of 5000 degrees and so on until at a depth of 1000 miles you get a temperature of 100,000 degrees, which is absurd. It is a generally accepted view that the earth's temperature increases more and more slowly as you go deeper and deeper, and after a certain point, say 200 miles, the rate of increase is hardly appreciable." The reason this calculation cannot be carried on indefinitely is clearly evident. The figures indicating the temperature become so large that, as Milne states, they are absurd. Even the temperature of the sun, the source of light and heat, is much lower according to Prof. Todd, who says in his astronomy: "The temperature of the sun is very difficult to ascertain. Widely different estimates have been made. Probably 16,000 to 18,000 degrees Fahrenheit is near the truth. But no artificial heat exceeds 4000 degrees Fahrenheit."

According to Moissau and Violle, who made such interesting and important experiments with the electric furnace, 6300 degrees Fahrenheit is the maximum temperature reached in the electric furnace, while others estimate the temperature to be as high as 8000 Fahrenheit. As a matter of fact we know nothing about such high temperatures estimated for the sun, and have no instruments to measure them, and when the estimates become so high they are more or less conjectural.

ELEVATION AND SUBSIDENCE.

Inasmuch as probably 95 per cent. of earthquakes are caused by faulting, that is, by breaking or caving in of the earth's strata, or by the slipping or sliding of the walls of a fissure after the fault has been formed, it becomes necessary to discuss briefly the subject of elevation and subsidence.

The crust of the earth is in a state of unstable equilibrium; parts of the country are rising and parts are sinking. This oscillation or change of level goes on, as a rule, very slowly, perhaps, like a mountain, building only a foot or two in a century, but sometimes it is paroxysmal. For example, in 1835, after a severe earthquake on the western coast of South America, it was found that the whole coast line of Chili and Patagonia was raised from 2 to 10 feet above sea level. The coast line of New Jersey is slowly sinking. According to former State Geologist Cook, the rate is from 2 to 3 feet in a century. This is undoubtedly correct. Old corduroy roads made of cedar trees are found submerged, and in some cases submerged stumps of trees also prove it.

The layman must distinguish, however, between land lost by slow subsidence and land lost by wave erosion and currents. The latter is much more rapid. For example, the land lost between Atlantic City, or better between Chelsea and Longport, is mainly due to wave and current erosion. A subsidence of two feet in a century in the vicinity of the sand dunes would have but little effect.

When the Coast Survey made soundings a few years ago over the submerged coastal plain in order to get the depth in fathoms out to the edge of the submerged continental platform, a distance of from 75 to 100 miles, they found beyond the mouth of the Hudson a submerged cañon which extended for many miles across the submerged coastal plain to the edge of the submerged continental platform. This cañon was said to be in some places nearly 2000 feet deep. As a matter of fact the maximum depth was 2400 feet. Through this cañon the Hudson River once flowed. The cañon undoubtedly shows subsidence.

Submerged cypress stumps off the coast of Carolinas and Georgia show subsidence. Off the coast of Maine are 365 islands and enough harbors and deep enough waters to float all the navies of the world. These islands are simply drowned hills.

When the coast line sank, the hills became partially submerged and the valleys entirely drowned. The deep water is where the valleys are. The rock on the island is of the same kind as that on the mainland.

The Gulf of Mexico, near the region of the delta, is an area of subsidence. The Missouri, which is really the Mississippi, rises in Montana. There is no good reason for taking the smaller tributary, which rises in Minnesota, as the main stream, because it flows due south. The Hydrographic Survey name the Missouri, which is the trunk stream, the Mississippi. This noble river brings to the Gulf of Mexico the wear and tear by erosion of the greater part of the North American Continent. Great slices of prairie soil 20 to 30 feet in thickness are carved off, so that it is well named the Muddy River. When we consider the millions of tons of sediment dumped into the gulf we wonder that it has not filled up long ago. Were it not for subsidence this sediment could never be accommodated.

When artesian wells are put down at New Orleans and in the delta region buried forests are found 200 feet below the surface with the trees standing upright. A popular resort or pleasure island once in the river below New Orleans has disappeared by subsidence.

The California coast is rising. The Coast Range of Mountains whose foot hills come down to the water's edge are still growing. The growth of mountains is very slow, perhaps a foot or two in a century. It is this elevation and faulting, and also the slipping of the walls of various faults, that make California an earthquake country. If the California coast were sinking there would be plenty of good harbors, because the ocean waters would come up the valleys of the Coast Range. As it is there is only one good harbor in California, and that is where the Coast Range of Mountains is dissected by the Golden Gate.

In Miocene times there was a land connection 60 miles wide betwen Alaska and Siberia. This is known as the Miocene Bridge. In those times the camel and the horse, both of which were natives of this country, and afterwards became extinct, roamed at will from Alaska to Siberia. The climate was then mild, and perhaps early man, who is a newcomer on this continent, came over from Asia. Be this as it may, the Miocene Bridge subsided long ago, but the Coast Survey that made us

more familiar with the submarine levels and contours of that region than we are with the interior parts of Alaska, tell us that the water is very shallow there.

The crust under the ocean is cracking and caving in, and the line of active volcanoes that marks the nearby region is very significant. Occasionally a new volcanic island pushes its head above the water. Earthquakes along the coast are frequent and severe. As before stated it is elevation and subsidence, causing faults, slipping, and rearrangement of the strata, that produce earthquakes.

The following table by Kayser from "An Introduction to Geology," by Scott, shows elevation and subsidence in different parts of the Globe.

NORTH AMERICA.

Rising	Sinking.
East coast of Greenland.	West coast of Greenland.
East coast of North America to 45° north latitude, Nova Scotia.	East coast of North America from Maine to end of Florida.
Part of Gulf of Mexico and Antilles.	East coast of Central America.
Pacific coast.	

SOUTH AMERICA.

Pacific coast except that of Peru.	Coast of Peru.
Atlantic coast from mouth of La Plata to 20° south latitude.	Atlantic coast except Uruguay and South Brazil.

ASIA.

Entire north coast and east coast to 30° north latitude.	East coast of southern China and Tonkin.
South coast and Malay Archipelago.	Laccadive and Maldive Islands.
Asia Minor.	

EUROPE.

Peloponnesus, Sicily, Sardinia, Ligurian coast, Balearic Islands, south coast of Spain, west coast of France, Ireland, Scotland, Scandinavia.	England, north coast of France, the Netherlands and Germany.

AFRICA.

East coast of Red Sea, west coast up to Gulf of Guinea.	Atlantic coast of Morocco, east coast of Tripoli, north coast of Egypt, Gulf of Guinea.

WHY SO FEW GEOLOGISTS STUDY EARTHQUAKES

In a signed article in the New York *Evening Post* Prof. T. A. Jaggar, Jr., of the Massachusetts Institute of Technology, is made to say: "A great convention of American geologists has

just completed its deliberations in Baltimore (Dec., 1908). All of these gentlemen are interested in earthquakes, but there are probably not more than half a dozen members of the society who have any technical or mathematical knowledge of them, and not many more who have ever experienced one. The idea that such experience was important for a geologist would be scouted as a jest."

The writer was inclined to take exception to Prof. Jaggar's statement and regard it as somewhat exaggerated, but after having read almost an entire page in one of our great dailies, after the Messina earthquake, devoted to the opinions of two geologists of prominence, one of whom is particularly capable, he came to the conclusion that there was considerable truth in Prof. Jaggar's statement. One of these gentlemen had evidently not looked up the subject since he had conned his college text-book. Then, in a more or less satirical vein, the Professor goes on to say:

> Many of these men are teachers in universities. If a Martian astronomer were to appear suddenly in their midst, after returning from a visit to the Lowell Observatory at Flagstaff, where his own existence had been so wonderfully interpreted, the following dialogue might be expected:
>
> "Where you know the heavens so well, of course your own earth is to you as an open book?"
>
> "Yes," reluctantly.
>
> "You have observatories for the recording of all earth phenomena."
>
> "No."
>
> "What! Did you not learn anything about local terrestrial motions before you studied the stars?"
>
> "No, we do not know anything about terrestrial movements."
>
> "Do you mean to tell me that you have not many instruments for observing them?"
>
> "We have the seismograph, but none of us understand it, and as for other earth motions, all we know we have learned from the physicist and the astronomer."
>
> "But you live on the earth, and must have to meet every crisis as it arises; can you foretell nothing?"
>
> "Well, you see, we don't think of it that way. We treat it historically, and make notes, and use a hammer and a compass, and are very much interested in the bones of Jurassic reptiles and in making maps of the rocks, and in finding out all about iron and coal. But we have no such precise knowledge as the astronomer."
>
> "But surely, in teaching your young men in the universities, you begin by precise instrumental study of the present earth and its processes, and have a vast accumulation of experience concerning those processes, in the form of tables, measurements, formulæ, curves, diagrams and computations?"
>
> "No, almost nothing has been done in accumulating experience or empirical data, except by the Japanese. When a volcanic eruption or an earthquake occurs we send a geologist to study the results, and he writes a thick and learned report. We do not know anything about what the conditions were during the months before the disaster. We teach our young geologists

first a little physics and chemistry, and a few generalities about earth process, and then set them to work mapping ancient rocks. The highest development of geology is the unraveling of the history of the past. We haven't time to go into prediction and humanistic geology."

THE SCIENCE OF GEONOMY.

The above is not exaggerated. The blame does not rest with the geologist; it rest rather with the haphazard growth of the science, and the proximity of the earth has made terrestrial observation and measurement difficult, in view of the littleness of man. This plea, however, can no longer be urged in extenuation of the neglect of the study of earth process. We have a considerable knowledge of physical science, and there are many instruments applicable to the earth. There is a very precise science known as geodesy, which has for its object the determination of the figure of the earth. There is geology, which aims to decipher earth history. Between these two there is needed a new science, many phases of which are now being studied, and this might well be named geonomy, the science of the laws which govern the earth.

There is one grave difficulty in the way of rapid development of this science, and that is expense. It is a science that calls for the establishment of observatories in many lands. These observatories will have for their objects the study of the changes which are going on in the crust of the earth under them and the relations of those changes to astronomical and meteorological changes. The new science, like astronomy and the study of the atmosphere, deals with moving things and so requires continuous local records, through weeks and months and years. Seismographs, microphones, magnetographs, gravity pendulums, pyrometers, tromometers, gas-collecting apparatus, and many special instruments adapted to local needs are among the devices with which an earth observatory should be equipped.

The natural places for establishing such observatories at first are lands where the earth movements are most rapid, regions of volcanoes and frequent earthquakes. The Japanese have taken the lead in such establishment, and their island empire is girdled with observatories. The writer has before him a pamphlet, in English, printed in Tokio in October, 1908, containing eleven contributions to practical seismology by a Japanese investigator, F. Omori, the first of which bears the significant title "On the Fore-Shocks of Earthquakes." Dr. Omori declares, "My belief is that a large destructive earthquake will be foretold in its epicentral region by some fore-shocks," and he substantiates his belief by exact instrumental proofs.

SICILIAN DISASTER PREDICTED.

With reference to Sicily, it is well to make note of the fact that an American volcanologist, Frank Alvord Perret, has predicted disaster on Mount Etna for two years past. Mr. Perret, who was decorated by the Crown of Italy for his splendid service to science and to humanity on Vesuvius in 1906, wrote in the World's Work of November, 1907: "By the rational methods of scientific research, we know that a great eruption of Mt. Etna is impending, the only uncertainty at present being which side of the mountain will break open." Great volcanic eruptions are preceded by great earthquakes, and the Messina disaster of December 28 comes on an earthquake date ("terrestrial maximum of gravitational stress") actually platted in advance by Mr. Perret on his diagrams for 1908. Like Dr. Omori, he is a man whose whole time is unselfishly devoted to these studies, but he has no observatory and no adequate means of support. A few business men in Springfield, Mass., last year came valiantly to his aid, and now their foresight is worthy of all honor. When young men think of making science their life-work, it would be well to remember Pasteur, and to consider carefully whether the "highest" development of the investigative faculties may not concern itself with humane rather than with historical

motives. To those who will give time and money to the establishing of earth observatories there will come, by way of reward, some of the most astonishing discoveries of the twentieth century.

Prof. Jaggar is especially interested in earthquakes and volcanoes, and has done excellent work in the latter subject.

Suppose for the sake of argument many of the younger geologists should begin the special study of seismology. They would have to take up their abode in some earthquake country like Italy or Japan, because this is not an earthquake country in the sense that Japan is. Severe earthquakes in this country are generally separated by long intervals of time. Of course there are exceptions. The specialist in seismology in this country would find himself more or less handicapped for want of local material and proper instruments. It would be like locating a college in the prairie country, where no rocks are exposed, and telling the students of geology to become proficient in stratigraphy, or telling the students who live along the gulf coastal plain to become experts in glacial geology. Environment is often a determining factor in deciding what investigations a man shall pursue in geology. At all events a man would have to be well equipped in the recent discoveries in modern seismology before he could make observations anywhere. What is undoubtedly needed are earthquake observatories at proper intervals over the country, and observers who are able to interpret the readings of the seismograph skilfully.

There are only about five seismographs in the United States, while Japan is girdled with observatories. There is one at the Weather Bureau Station at Washington, one at Johns Hopkins University, Baltimore, one at Harvard University, one at the Yerkes Observatory, Wisconsin, and one in California. Every large college and university should have a seismograph. The use of a seismograph was strikingly shown in Australia. Two breaks occurred in the cable, one in 1880, the other in 1888. The inhabitants were shut off from communication with the mother country, England, and the rest of the world. They were in a state of uncertainty and dread, not knowing whether war had been declared or whether some hostile foe had cut the cables. The troops were called out and put in readiness and nineteen days elapsed before a word came. A seismograph at the capital would have soon reassured them and shown that the break was due to a submarine earthquake.

PROF. JOHN MILNE AND HIS DISCOVERIES.

Milne is the foremost seismologist to-day, and received his education at King's College, London, and the School of Mines. He was employed by Cyrus Field, of cable fame, soon after his graduation to report on some coal fields in Newfoundland. His next offer was from Japan, which country was then securing the best foreign talent available to exploit her mineral resources. Japan probably offers a better field for the seismologist than any other country, and Milne's attention was soon directed to the study of seismic phenomena for the Japanese. He taught them how to build their houses and bridges earthquake proof as far as possible. He devised a number of seismographs, some simple in construction, others more intricate and exceedingly delicate.

Japan appreciated his studies and results and placed him in the chair of seismology at the university. Some of Milne's preliminary experiments were made by drilling holes of various depths in the solid rock and exploding dynamite. The emperor took a keen interest in the experiments to determine the velocity and direction of the wave motion, and often himself exploded the charge with an electric button. Milne spent twenty years in the study of earthquakes in Japan, and finally returned to England, where his observatory for the study of seismology is located at Shide, on the Isle of Wight.

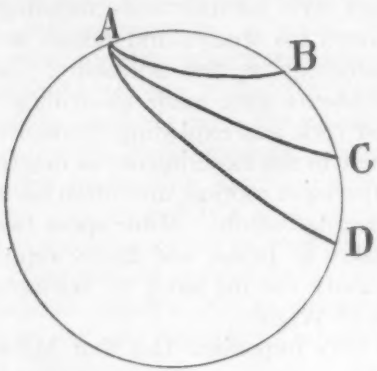
There is one very important fact that Milne proved several years ago, namely,

DISTANT EARTHQUAKE WAVES TRAVEL STRAIGHT THROUGH THE SOLID ELASTIC EARTH BELOW THE CRUST.

This is probably the most important discovery made in recent years in seismology, and one which the general public and some of the writers of text-books have not grasped as yet. It is doubly important from the fact that, notwithstanding that the study of the different theories about the earth and its interior is a very obscure one, this proof of Milne's helps us to eliminate and discard the thin crust and molten interior view, and also the theory of a solid crust and solid interior with a pasty or viscous layer sandwiched between.

It is very evident that an earthquake wave requires a solid and elastic medium for its propagation, and it could not travel from Japan to England below the crust through a molten mass,

which is not, of course, solid or elastic. And it is also very evident that if we consider the pasty layer view in reference to this proof of Milne's, it will not hold, because the earthquake wave would have to pass through two pasty layers before reaching England, neither of which is elastic or suitable for the propagation of earthquake waves. Now what proof has Milne that the earthquake wave travels through the solid earth first and not around the crust? Namely, this: He says, for example, if an earthquake wave were to travel from Japan to England through the crust around the circumference, we would get two messages—the one traveling through the shortest arc of the circumference we would get first and the one coming the longest



distance we would get last, because the waves would travel in both directions. Now as a matter of fact we only get one message through the solid earth, traveling along the chord of an arc.

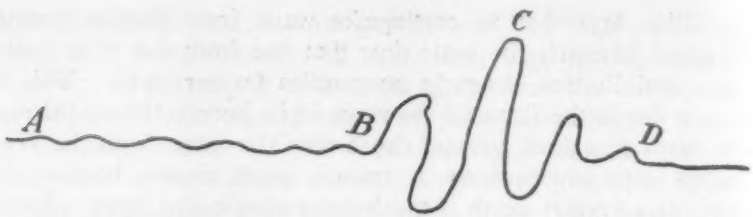
We are indebted to articles by Milne, and also to an excellent interview by Cleveland Moffett with Milne, for the interesting and popular way in which some of these facts are set forth. For example: If an earthquake starts at A, it will travel through the solid earth first from A to D along the chord AD, also from A to C and A to B. The other and later waves travel along the surface from A B C to D a considerable time afterward. It travels through the solid elastic interior much more rapidly than it does through the fissured crust. All the waves from far-distant earthquakes reach the Isle of Wight in practically the same time. They travel from Japan, Borneo, and Java to England in about 16 minutes.

Milne says that an earthquake wave from Borneo reaches England in nearly the same time that one from the West Indies does, and Borneo is nearly 2000 miles farther away. This he says is due to the fact that the wave from Borneo travels through the earth at a much greater depth than the wave from the West Indies, and consequently it travels much faster, because the earth at a greater depth is much more elastic and rigid. Earthquake waves that start on the opposite side of the globe travel much more quickly than those that start on our side of the globe because they travel deeper through the more rigid elastic interior. In fact the shock of a nearby earthquake may reach us through the crust. Moffett asked Milne a leading question when he said: "If all the earthquake waves on the opposite side of the globe reach England in practically the same time, how do you know in what place or country the earthquake started?"

CAN THE SEISMOGRAPH INDICATE IN WHAT COUNTRY THE EARTHQUAKE STARTS?

Milne stated we recognize waves that start from different countries, Japan, Borneo, India, South America, and other countries by their signatures or seismograms recorded by the seismograph. For example, an earthquake wave that has traveled 3000 miles makes a different signature on the photographic paper or smoked paper of the seismograph from a wave that has traveled 5000 miles. One that has traveled 7000 miles makes still another record. The different signatures are due to the distance traveled: For example, below is a message recorded by an earthquake that has traveled a shorter distance than 3000 kilometers.

After the same wave has traveled 9000 kilometers, the wave would record at another station a message or seismogram somewhat like this



If the wave traveled a longer distance the message would be stretched out still more.

When a great earthquake takes place on the other side of the globe, the first waves to reach the observer on the Isle of Wight or any other far-distant station are the so-called first preliminary tremors recorded by the seismograph. These are the waves that have traveled through the rigid earth far below the crust. They have taken a short route and traveled along the chord of an arc connecting the place where the earthquake started and the observatory where the seismographs are located. These are the longitudinal or compressive vibrations. The large waves of the main shock travel after these preliminary tremors. These large waves, according to Hobbs, have in the severest earthquakes "a length sometimes of 34 miles and a rise and fall of no less than 20 inches. They appear, therefore, to travel like a slow swell along the earth's surface." In both the above figures the point A, where the line begins to assume a wave-like structure, marks the beginning of the earthquake. The wave-like line A B shows the preliminary tremors which invariably precede heavy shocks. The large waves which produce the heavy shock are shown at C, and D marks where the earthquake tremors slowly become extinct.

Milne states that "it is mostly in these preliminary tremors that earthquakes reveal their identity. These are the rapid waves, but the slower they come the longer it takes to record them, and the more stretched-out they become in the seismogram. And by carefully noting these differences, especially the time it takes to record the tremors and the large waves, we get our information. Now the time it takes to record preliminary tremors by the horizontal pendulum of the seismograph is known for Borneo, Java, Japan, region east of Newfoundland, West Indies, and other places. Hence we can tell how far distant in miles from the observer the earthquake occurred. The time it

takes the shock to travel through the earth should not be confused with the time it takes the seismometer to record it.

"Other observatories have similar data. An earthquake, for example, occurred so many miles from the Isle of Wight, a certain number of miles from Batavia, so many miles from Argentina. We can with the help of a pair of compasses on the map fix the place beyond question."

LASKA'S RULES (HOBBS) FOR FIXING THE DISTANCE OF SEAT OF DISTURBANCE IN REMOTE EARTHQUAKES.

"If V1 be the time in minutes of the commencement of the preliminary tremors, V2 that of the second preliminary tremors, and B that of the main waves in the seismogram; and if Δ be the distance in megameters (1 megameter equals 1000 kilometers or about 621 miles) then

$$1 + \Delta = V2 - V1 \text{ and}$$
$$3\Delta = B - V1.$$

"It has been proved by many determinations that these formulas are correct to a close approximation. They may be stated in simple form as follows:

"(1) The duration of the first preliminary tremors in minutes less one is the distance of the seat of the disturbance in megameters.

"(2) The duration of all the preliminary tremors in minutes is thrice the distance of the seat of the disturbance in megameters."

LOCATION OF A DISTANT EARTHQUAKE FROM THREE STATIONS (HOBBS).

"It is evident that if the distance of an earthquake from the observing station may be accurately determined, its distance from three or more widely separated stations is sufficient to fix its location upon the earth's surface. From two such stations its location is fixed as at one or the other of the points where the arcs described (upon a globe) from each station with radii equal to the distance as determined from these stations, intersect each other. The arc described by the same method from the third station tells which of these intersections corresponds to the locus of the earthquake. A lack of precision in any of the determinations tends to be corrected as arcs are described from a larger number

of stations, and the probability of considerable error may be gauged from the size of the so-called triangle of error at the intersections. The simple principle involved in this method will be clear from inspection of the map."

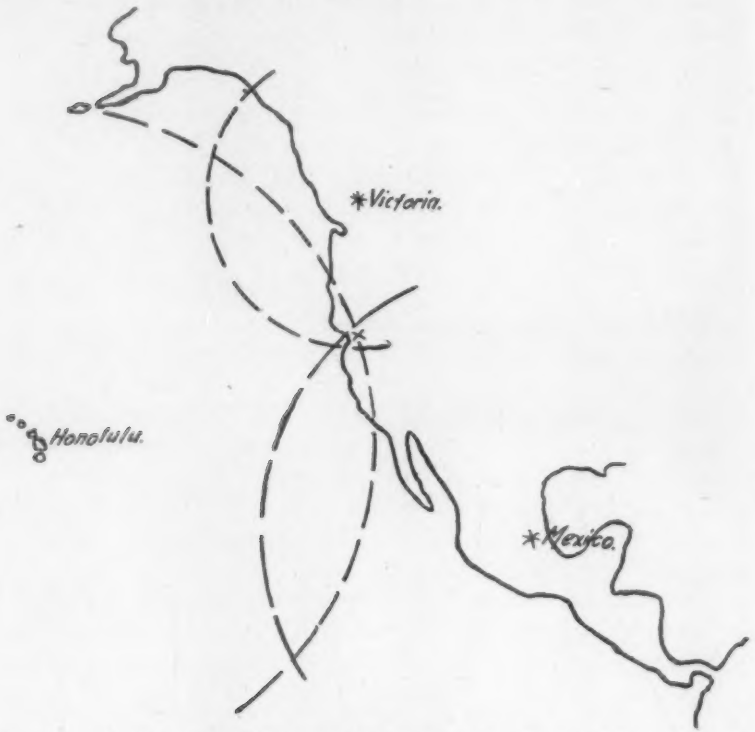


Diagram to illustrate the location of an earthquake from observations made at three widely separated stations.—*From Hobbs.*

THE LARGE EARTHQUAKE WAVES.

When a portion of the crust of the earth suddenly caves in, or when a great fissure opens in the crust extending across the country for miles, or when the walls of a fissure already formed and cemented together slide horizontally or vertically, then, besides the waves of compression which travel through the interior of the earth, there are other waves known as the large waves that travel along the earth's surface. They travel like a slow swell, the crust is lifted up in long waves. After these waves have traveled great distances across the continent, Milne has calculated that then they measure from 20 to 40 miles from crest to

crest, and their crests or swells rise two or three feet above the level, so that mountain ranges, hills, plains, and entire cities are lifted up a foot or more and settle down again all together so evenly and so very slowly that the observer does not notice it, but the seismographs record it. In this way London, Paris, New York, and Chicago are raised and lowered many times during a year by these waves. It takes from 10 to 20 seconds for these waves to rise, and from 10 to 20 seconds for them to fall according to Milne.

The earth's crust is very elastic and is continually pulsing and quivering with tremors caused by earthquake disturbances that take place on the opposite side of the globe. It rises and falls like the ocean. The ground rises and falls with the smaller of these great waves about three inches, that is, it rises slowly, taking about 15 seconds, and then subsides slowly, taking the same time. In this way an entire city may rise and fall, but so slowly that the observer cannot feel or notice it, but the seismograph records it at once.

The rise and fall of these great waves a foot or more, and so slowly that the observer does not notice it, is the most difficult statement for the layman to believe. Prof. Hobbs, geologist of the University of Michigan, an authority on seismology, makes the same statement in his book, where he says: "The large waves of the great Indian earthquake of 1897 had a complete period of 22 seconds, a length of 34 miles, and a rise and fall of no less than 20 inches. These waves therefore appear to travel like a slow swell along the earth's surface, and they would be felt by individuals save only for the extreme slowness of their motion. The first preliminary tremors from this earthquake had an estimated period of 0.5 to 0.8 of a second and their amplitude was but a fraction of a millimeter.

IS THERE ANY CONNECTION BETWEEN VOLCANOES AND EARTHQUAKES?

It has long been known that volcanic regions are regions of frequent earthquake. This has led many to think that there is an intimate connection or relation between the two. Notwithstanding the fact that earthquakes often accompany volcanic eruptions, and the coincidences are very striking, we have very many instances also of earthquakes occurring in regions far removed from volcanoes, and also in volcanic regions when there is no

connection between the two. Milne puts the subject in this way: "The residents of a volcanic country, when seeking for the origin of an earthquake, invariably turn towards the volcanoes which surround them. If a neighboring volcano is in a state of activity, it is often regarded as a safeguard against seismic convulsions. In other cases it is looked upon as the cause of such disturbances. In a few instances both of these views have apparently been corroborated.

"When we consider that an earthquake and a volcanic eruption may both be the result of some great internal convulsion, and that first the one and then the other may take place in the same neighborhood, it is natural to expect that when these internal forces have expended themselves in the production of one of these phenomena, it is not so likely that they should manifest themselves in the other. The inhabitants of Sicily and Naples, we are told, regard eruptions of Etna and Vesuvius as safeguards against earthquakes. From an examination of the records of the large earthquakes and the volcanic eruptions which have taken place during the last 2000 years, Dr. Naumann found there was often approximate coincidence between the times of the occurrence of these phenomena, suggesting the idea that the efforts which had been sufficient to establish the volcano had at the same time been sufficient to shake the ground. Many of the great earthquakes of South America do not appear to have been connected with volcanic eruptions. The great earthquakes of the world, like those of Calabria and Lisbon, which took place in regions that are not volcanic, have not, as Fuchs tells us, taken place in conjunction with volcanic outbursts. In Japan and in the Sandwich Islands, and in many other parts of the globe, the small earthquakes which occur almost daily do not appear to show any connection whatever with volcanic disturbances."

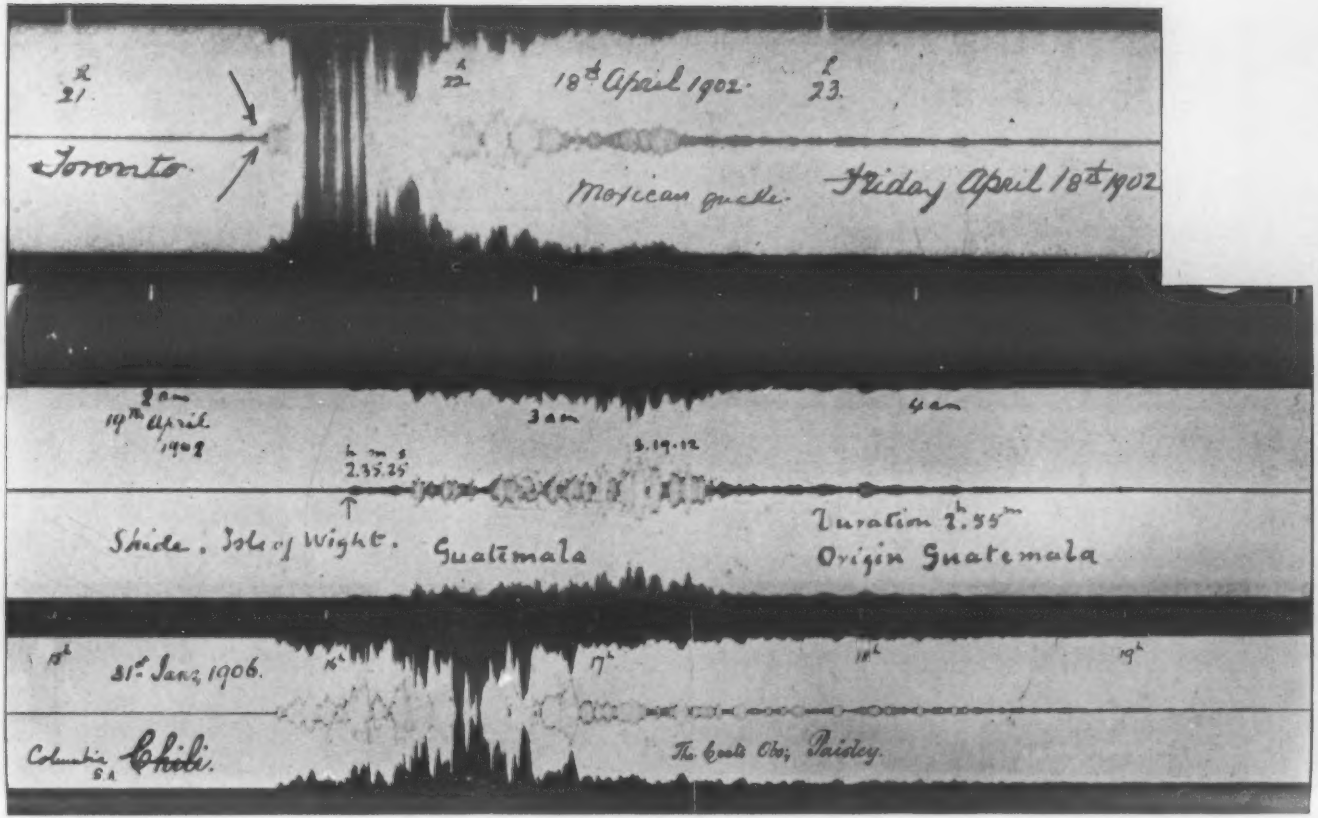
To Milne's list of the great earthquakes of the world which had no connection with volcanic outbursts may be added the San Francisco earthquake, the Jamaica earthquake, and the Messina or Sicilian earthquake, 1909. Milne then instances examples of the synchronism of earthquakes and volcanic eruptions. One of the earliest was the destruction of Herculaneum and Pompeii by an ash and cinder shower 79 A. D., accompanied by severe earthquake.

At the time of the eruption of Kileau in 1789 the ground shook and rocked so that people could not stand. The first

eruption of the volcano Irazu in Costa Rica, in 1783, was accompanied by violent earthquakes. At the time of the great earthquake at Concepcion, in 1835, while the waves were coming in, two great submarine eruptions were observed. In 1797, when Riobamba was destroyed, the neighboring volcanies were not affected, but Mt. Pasto, 120 miles distant, suddenly ceased to throw out its usual column of water. On the night of December 10, 1874, a strong shock was felt in New England, while at 4.45 A.M. on December 11 a shock was felt in the Pic du Midi, in the Pyrennes. In the middle of December there were volcanic outbursts in Iceland. Milne then says, "It is possible that these occurrences might be the results of some widespread disturbance beneath the crust of the earth or perhaps of widely-extended earth pulsations. The probability, however, is that these coincidences are accidental. When we remember that in a small area like the northern half of Japan alone there are periods when at least two shocks per day occur, on the average, it is impossible for these coincidences not to exist. Less frequently coincidences between the larger disturbances must occur. Over and above these accidental coincidences, it would appear that in the world's history there have been periods when earthquakes were unusually frequent, and at such times distant countries have suffered simultaneously. This does not imply an exact synchronism in the single shocks. Small earthquakes or, more properly speaking, local tremblings are a necessary accompaniment of almost all volcanic eruptions. Tremors of this description are seldom, however, felt beyond the crater, or at the most upon the flanks of the mountain where the eruption is going on. They are due to the explosive action of steam bursting through the molten lava."

Besides the illustrations given above by Milne we might mention a most striking coincidence that took place after his book was written, namely, the severe earthquakes in California known as the San Francisco earthquake, and the severe eruption of Vesuvius, which took place at nearly the same time. This gave rise to a widespread discussion at the time by the general reader as to whether there was any possible connection between the two. There is no direct connection, of course, between the two. Between these far distant places we have that profound depression, the Atlantic Ocean, and a continent crowned with massive mountain ranges.

The writer heard a member of the California earthquake com-



From originals furnished by Prof. John Milne, Shide, Isle of Wight.

mittee state in a lecture that the reason for the coincidence was the general seismic condition of the globe. This may be correct, but is rather indefinite, and it is desirable to know what is the cause of the general seismic condition of the globe at any given time of unusual activity in earthquakes or volcanoes.

If we could only believe the theory that the combined pull of the sun and moon when in a favorable position exerts such an enormous attractive force on the earth, parts of which are in a state of fearful stress and strain and ready to break, crack, slip, or slide, and that this attractive force does not produce a break necessarily, but only determines the time when the break occurs, then we could explain the synchronism of earthquakes and volcanoes on different parts of the globe or, better, in different parts of the same country. When the fissure forms or the walls slide, the earthquake shock or wave travels, and the compression and readjustment of the walls of fissures sometimes squeeze out the lava forming volcanoes.

Prof. Perrey, of Dijon, who did so much for seismology and devoted a lifetime to a preparation of a catalogue on earthquakes, held the view that the abundance of earthquakes at certain seasons was due to the attractive force or combined pull of the sun and moon. Rudolf Falb, whose predictions and writings have attracted attention, inclines to this view and endorses Perrey's conclusions. In 1873 he predicted the destructive earthquake of Belluno. In 1874 he predicted the eruption of Etna.

Milne states: "That earthquakes are slightly more numerous at these particular periods than at others is a strong reason for believing that the attractions of the sun and moon enter into the list of causes eventually culminating in these phenomena."

Hobbs seems to think that Perrey's data are negative, because he says: "Perrey wished to find out whether earthquakes stand in any relation to changes in the moon, and while the results of his study, as generally interpreted, furnish a negative answer to his query, the investigation has nevertheless yielded a most important contribution to the science of seismology."

As regards the relation or connection between earthquakes and volcanoes, Hobbs takes the same view as Milne. He says: "It has long been recognized that the earthquake zones of the globe are also the zones of active volcanoes. It cannot be denied that the coincidence is one of great significance, but the relation

of one phenomenon on the other is not that which has generally been supposed. In the clearer light of to-day we are able to say that volcanoes and earthquakes alike are due to the action of those forces which have built up the near-lying mountain ranges. To form such mountains it was necessary for great strips of the earth's crust to be pushed up in successive movements between lines of fissures. The jolting movement of the earth blocks as they have slipped over each other accounts for the earthquakes, and the melted rock material, which as a result of the movement has been squeezed out, either along the fissures or, as is more frequently the case, at their intersections, has built up the volcanoes. Wherever mountains are still growing, earthquakes and active volcanoes are to be found. Where they have ceased to grow, there the earth does not shake—it is dead and lava is no longer exuded through the fissures in the surface." While this statement in the main is correct we might find an exception to it in the Charleston earthquake.

EARTHQUAKES AT SEA.

Inasmuch as three-fourths of the surface of the earth is covered with water it is to be expected that submarine earthquakes are very frequent. Not only are they frequent, but they do fearful and appalling damage, as they are responsible for the enormous earthquake waves at sea. A wave of water 20 to 80 feet or more in height advances on the lowlands or rushes up the estuaries, submerging entire villages and sometimes landing large vessels high and dry. An earthquake, the epicentrum of which is often hundreds of miles from shore, is sometimes responsible for the snapping or breaking of submarine cables, and when these breakings are frequent the loss to the companies is enormous.

The topography of the ocean bottom is different from the relief of the dry land. There are submarine mountain chains and submarine volcanoes that rear their crests above the ocean as thousands of islands in the Mid-Pacific and elsewhere. These submarine mountains are not dissected by canyons and ravines like the mountains on the surface, because there are no rivers, rain, frost, and gases of the atmosphere to carry on the work of erosion.

Oceanography, like seismology, is a new science, started since

the middle of the nineteenth century. The general outlines of the coast have been known since the time of the early explorers. The exploration of the sea bottom by soundings in deep water was first made in 1840 by Sir John Ross, who was the first to do deep sea dredging.

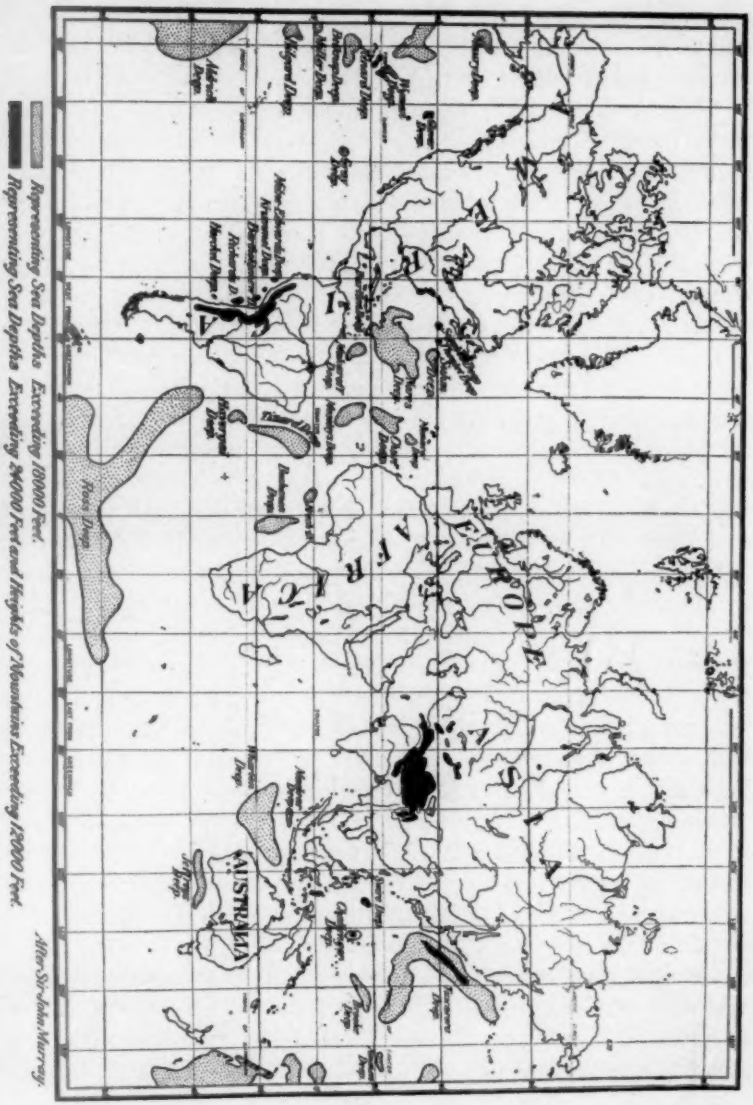
It was not until 1872 that we learned much about the ocean bottom. During that year the Challenger was fitted out by Great Britain to study the ocean bottom and its fauna. Some of the best scientists superintended the work, and for four years she sailed the oceans of both hemispheres, dragging the bottom with nets and dredges and sounding the greatest depths with steel wire carrying an iron weight.

After the return of the Challenger it took nearly twenty years to study and corrollate the immense and varied amount of material and data collected. Leaders in science in different countries helped. Sir Wyville Thompson and Sir John Murray, of England, Haeckel, of Germany, Agassiz, of the United States, Rénard, of Belgium, and others of equal prominence helped to make the fifty royal octavo volumes that make up the history of the sea and its depths. The vessels of other nations have continued the work, and the Blake, of the United States Coast Survey, has done excellent work with others, so that we know more about the coast line and the depths along Alaska, for example, than we know of the interior.

A great portion of the ocean bed is flat, but there are mountain ranges, broad plateaus, great depressions like valleys, very steep slopes or scarps, like those that wall in the great depths, and lastly the steep slopes at the edge of the submerged continental platforms. Cuba and the surrounding islands are the crests of submerged mountain chains. The Pacific is narrow and shallow near Behring Strait, but opens wide farther south. The vast number of islands in the Pacific show that the numerous mountain ridges of which they are the tops trend northwest and southeast. Soundings made by the Challenger and other vessels show abyssal depths in certain parts of the Pacific. The Tuscarora deep, east of Japan, extends from the Philippines to Java, one sounding reached 27,930 feet. The Aldrich deep, northeast of New Zealand, reaches a maximum depth of 30,930 feet. The deepest sounding in the Pacific is 31,614 feet, known as the Challenger deep, sometimes called the Nero deep, south of the

Ladrone Islands, and lacks only 66 feet of being 6 miles in depth. A short distance off the west coast of South America are five widely separated deeps reaching 24,000 feet.

The bottom of the Atlantic is traversed by a ridge running the length of the ocean and dividing it into two great troughs or valleys from 15,000 to 20,000 feet deep. One valley is on the American side of the ocean and the other extends south from the British Isles. The mountain ridge separating these valleys ends in mid-ocean in about the latitude of the Cape of Good Hope, so that a broad basin extends down to the Antarctic regions, where Ross deep is encountered, from 18,000 to 24,000 feet in depth. The greatest sounding in the Atlantic is the Blake deep, near Porto Rico, 27,366 feet. Off the eastern coast of the United States for 75 to 100 miles out the water is shallow, because there lies the submerged coastal plain, and when a vessel is wrecked there the masts stick out of the water, but where this coastal plain ends is the edge of the continental platform, and the ocean goes down abruptly to abyssal depths. In this brief description of the ocean bottom, which is necessary for an understanding of submarine earthquakes, only a few of the great depths are mentioned. An inspection of the rough sketch map after Sir John Murray will show some of the others. These, according to Milne, are the great danger regions of the oceans' beds and enormous sums could be saved the cable companies if we knew their exact boundaries. Whenever we come to a sudden slope or scarp or precipice in the ocean extending abruptly for many fathoms down, we can safely say this is a danger point. He says: "There have been submarine earthquakes like that of June 15, 1896, that have shaken the earth from pole to pole. Cables from Java have been simultaneously broken, and in 1890 three cables to Australia snapped in a moment. The great majority of breaks in the North Atlantic cables have occurred in the deep 300 miles east of Newfoundland, where there are two slopes, one from 708 to 2400 fathoms in a distance of 60 miles, and the other from 275 to 1946 fathoms within 30 miles. On October 4, 1884, three cables lying about 10 miles apart broke simultaneously at this spot. The significance of such breaks is greater when you bear in mind that cables frequently lie uninjured for many years on the great level plains of the ocean bed where seismic disturbances are infrequent."


Representing Sea Depths Exceeding 10000 Feet.
Representing Sea Depths Exceeding 24000 Feet and Heights of Mountains Exceeding 12000 Feet.
EUROPE
AUSTRALIA
Ross Deep
After Sir John Murray.

Cables are broken by subsidence when large areas sink bodily. This is known as faulting, and the cable is carried along and broken. This subsidence or faulting on a large scale often produces an earthquake wave at sea, the shock traveling first through

the solid rock followed by the great sea wave. Cables are broken also when enormous rock masses descend a steep slope. All submarine earthquakes, however, do not produce sea waves.

The connection between this brief statement of the topography of the ocean bottom and submarine earthquakes, and the lessons to be learned are that earthquakes of great intensity are more likely to occur where the steep walled great deeps are located, or where there are steep scarps or abrupt submarine precipices, because by the slipping of the walls of a fault, subsidence, or caving in of the ocean bed is more likely to occur there. These are the great danger spots for cables on account of these phenomena which produce submarine earthquakes.

As before stated, cables laid on even submarine plains, plateaus, or in great valley-like depressions may remain unaffected for years, because subsidence or caving in of the strata which causes the earthquake is more infrequent there. This rule is not invariable, however, because earthquakes may occur anywhere on the ocean floor. Moreover, submarine earthquakes are not always accompanied by the enormous sea waves, neither is the water always agitated on the surface. Vessels receive sharp jolts or jerks, and often a severe shaking, and yet the water is unruffled on the surface. "On February 10, 1716, vessels in the harbor of New Pisco were so violently shaken that both masts and ropes were broken, and yet no motion in the water was observed. Some have described these shocks like those which would be produced by the sudden dropping of large masses of ballast in the hold of the vessel." Milne states: "From the rattling sound which has accompanied some of these submarine shocks, many of which have never been recorded as earthquakes on the neighboring shores, it does not seem improbable that they may have been the result of the sudden condensation of volumes of steam produced by submarine volcanic eruptions. As confirmatory of this supposition we have the fact that many of the marine disturbances, which might be called seaquakes, have been observed in places which are close to or in the line of volcanic vents."

Most of the submarine earthquakes have been recorded on shore. "For example, at the time of every moderately severe earthquake which has shaken Yokohama, the same disturbance has been felt on board the ships in the adjoining harbor. In some cases the effect had been as if the ship was grounding, in

others as if a number of sharp jerks were being given to the cable. At the earthquake in St. Thomas, in 1868, it is said that the water receded shortly before the first shock. When it returned after the second shock, it was sufficient to throw the United States ship Mononghela high and dry. Another American ship, the Wateree, was also lost in 1868, being swept a quarter of a mile inland by the sea wave which inundated Arica, The sea waves of 1877 removed it still farther inland. At the time of the Jamaica earthquake, in 1692, the sea drew back for a distance of a mile. On October 28, 1724, Lima was destroyed, and on the evening of that day the sea rose in a wave 80 feet high over Callao. Out of the 23 ships in the harbor, 19 were sunk and 4 others were carried far inland. The first movement which is usually observed is a drawing back of the waters, and this is so well known to precede the inrush of large waves that many of the inhabitants of South America have used it as a timely warning to escape towards the hills, and save themselves." During the Charleston earthquake of 1886 there were hundreds of vessels in the vicinity, but only five felt the shock and these were located in a line with the greatest disturbance on land. A ship, the Nina Mathilde, when 37 miles northeast of Charleston Light, received such a severe shock that the crew were thrown out of bed. This ship was in an unusually favorable position to receive shocks over the line of disturbance.

SEISMOGRAPH.

Seismometers or seismographs, as they are more generally termed, are instruments for detecting or measuring the earthquake shock or wave. Some of the modern ones are extremely delicate and sensitive, so sensitive, in fact, according to Milne, that if the solid column of masonry communicating with the rocky floor be pressed with the hand, the seismograph which rests on the masonry will be affected, and the horizontal boom or pendulum will be set in rapid vibration. If two Milne seismographs provided with horizontal pendulums be put on high buildings opposite each other on one of London's traffic streets when crowded with the heavy drays, they will show that the tops of the buildings bend over slightly towards each other.

Rude forms of seismographs were in use for indicating the direction from which the shock came long before the most elementary facts about seismology were known. One form long in

use and of simple construction was a circular vessel filled to the top with mercury. Around the top was a ring of holes corresponding in position to the points of the compass. During an earthquake shock the vessel was shaken and the mercury spilled out into a compartment. A shock from the southeast would spill the mercury into the northwest compartment. The earliest self-registering seismograph was simply a vertical pendulum with a flexible marker on the bottom, which made a mark when it was shaken by an earthquake on a flat glass plate underneath. The simple vertical pendulum registers only the horizontal movements of the earth.

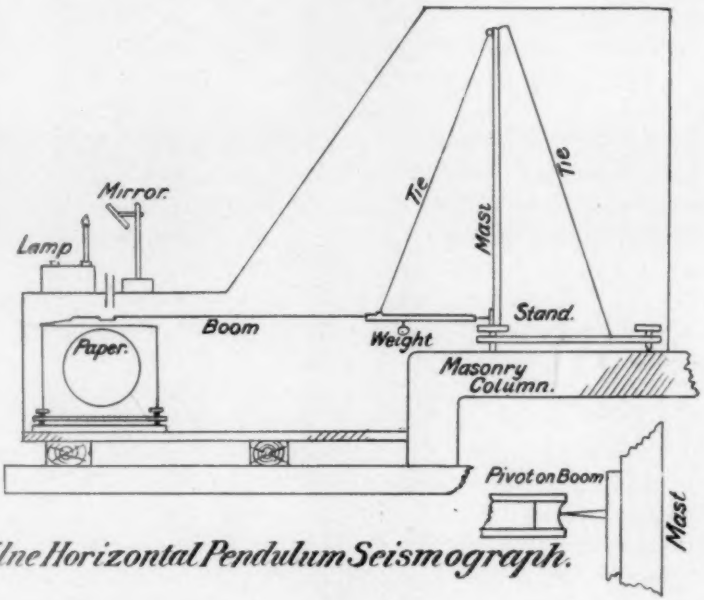
What is needed is the recording of the vertical movement as well as what corresponds to the north and south and east and west movements. Most of the recent seismometers register horizontal movements. The horizontal pendulum consists of a mast to which a boom or pendulum moving horizontally is attached by a stay from the top of the mast. The boom ends in a steel point which fits in a concave agate on the mast to insure freedom of movement. The other end of the pendulum which vibrates horizontally is provided with a needle or marker which records its movements on a piece of smoked paper moved by clockwork. Sometimes there is a pen on the end which marks on the white paper. In another form the motion of the beam is photographed on paper on a revolving drum moved by clockwork. It is necessary to get the exact time of arrival of the earthquake. In order to do this a clock with an error of not more than two seconds per week is employed.

The Agemennone, Vicentini, and Weichert seismographs consist of single vertical pendulums. The Von Reuber-Ehlert, Milne, and Omori seismographs have horizontal pendulums. There is a seismograph that registers the vertical motion of the earth. The horizontal pendulum seismographs are always used in pairs. One is arranged so as to register the north-south component of the earth motion, the other the east-west component.

Prof. C. F. Marvin, of the Weather Bureau, who has made some ingenious improvements in registering the seismogram or earthquake message, says: "None of the existing seismographs is adapted to register all kinds of earthquake motion. If we wish to record microseismic motions we must get one sort of instrument, a different instrument for the satisfactory registration of large distant disturbances, and a third type of instrument

for damaging or destructive shocks. The existing instruments of the first two types, if not completely cracked when subjected to destructive shocks at least are seriously disordered in most cases and their records falsified and interrupted.

"If one sets out to equip a seismological observatory he finds himself obliged to instal a large number of instruments. Not only must these be of different types, adapted to the different degrees of intensity and character of earthquake motion, but in many cases at least two instruments of each type are necessary,



Milne Horizontal Pendulum Seismograph.

since we have two components of horizontal motion to register, and the horizontal pendulum can record only one component of motion."

Omori states: "No single seismograph can record clearly all the different sets of vibrations comprising the earthquake motion, when the slow component is of large amplitude. At least two instruments are required for the horizontal or vertical motion."

Prof. Wiechert, in 1907, invented a seismograph that would not only record the far-distant earthquakes of great intensity, but also the local earthquakes.

Prof. Milne's seismograph of the horizontal pendulum type is readily understood from the accompanying diagram. The mast is 50 c.m. high, the boom is 120 c.m., or about four feet long. A wire stay or tie from the masthead supports the boom. The other end of the stay is fastened to the stand. A small weight keeps the boom taut. A knife edge or steel point projects from the bottom of the mast and fits into an agate cup at the end of the boom. This insures freedom of motion for the boom so that it can vibrate horizontally whenever disturbed by an earthquake. An inclined mirror reflects the light from a lamp. The end of the boom has a thin piece of metal with a hole or slit. Underneath the mirror is a box containing a roll of photographic paper driven by a clock. In the top of the box is a small slit directly under the slit in the boom. A beam of light reflected by the mirror through the two slits makes a point on the paper. When the boom is disturbed by an earthquake it vibrates horizontally and traces a sinuous line on the photographic paper.

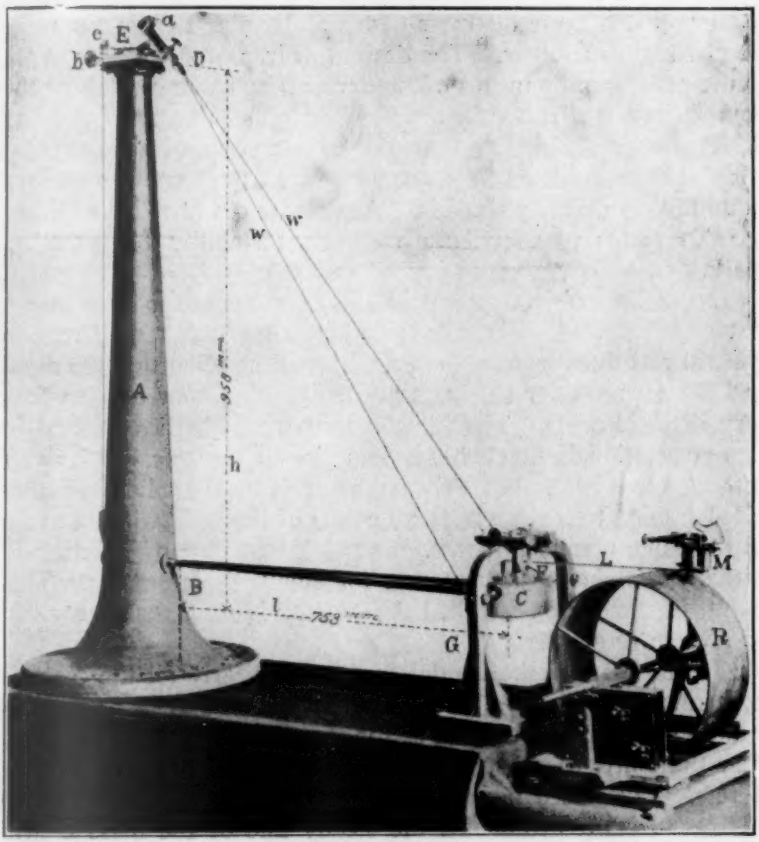
The following illustrations of a Bosch-Omori horizontal pendulum seismograph at the Weather Bureau are taken, together with his description, from an article on the Omori Seismograph at the Weather Bureau, by C. F. Marvin, Professor of Meteorology.

THE WEATHER BUREAU SEISMOGRAPH.

"The instrument as set up to photograph is shown in Fig. 1. As actually installed in a small basement room of the Weather Bureau, the separate castings are secured to thick blocks of stone cemented firmly into the concrete floor of the building and projecting but a few inches above the floor level. The heavy casting *A* forms the support for the so-called horizontal pendulum *B C D*. *C* is a massive lead weight, rigidly attached to the conical tubular rod *B*, the end of which, at *B*, terminates in a hardened steel plug, hollowed out cup-wise and highly polished. At this point the pendulum is supported upon a sharp, conical pointed stud of hardened steel fixed to the casting *A*. The remaining support for the pendulum consists of a pair of steel wires, faintly seen at *w w* in the picture. At the weight end these are attached to eyes with a knife-formed inside edge and there engage two studs that project laterally from the mass *C*. At *D* the wires are united to a stirrup, which at the point opposite the wires is provided with a bit of hardened steel formed with a

cut-shaped recess and highly polished. Here the stirrup is supported on a sharp, hardened steel cone attached to the carrier *E* forming the summit of the casting *A*. The carrier *E* is provided with several adjusting screws; thus, *a* serves to raise or lower the

FIG. 1.



Bosch-Omori horizontal pendulum seismograph at the Weather Bureau. From originals furnished by the U. S. Weather Bureau.

weight *C* and thus adjust it to a horizontal position, while *b* causes the point at *D* to move away from or near to the top of the column, and, finally, a pair of screws, one of which is seen at *c*, gives *D* a lateral motion in the horizontal plane. In short, the pendulum *B C D* is supported at *B* and *D* on sharp steel points

and swings therefore with great freedom of motion. If the points *B* and *D* are rigorously in a vertical line, the pendulum is in neutral equilibrium and the mass *C* will then remain at rest in any position. For practical work, however, a small degree of stability must be imparted to the mass *C*, otherwise minute changes of temperature and other influences which it is impossible to control will cause the mass *C* to wander about from one position of rest to another. The desired degree of stability is given to the pendulum by means of the screw *b* and the azimuth of the point of rest is adjusted by the screws *c*. The degree of stability is determined by noting the time of vibration of the mass *C*, which can be adjusted to swing as slowly as one complete vibration in thirty or forty seconds. A period of twenty-five to thirty seconds seems to contribute a sufficient stability for practical work.

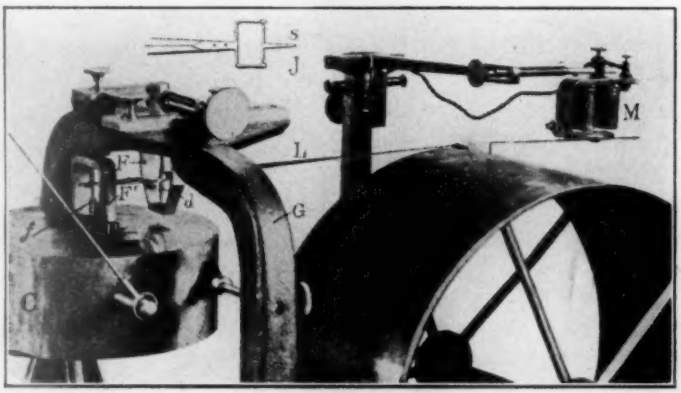
The whole object sought in this construction is to secure a "steady mass," as it is called; that is, a mass that shall remain quite at rest during an earthquake, notwithstanding that the earth and the supports for the mass are undergoing appreciable vibratory displacements. The kinetic property of bodies utilized in this connection is that which gives rise to the so-called *axis of instantaneous rotation.* Whenever any force is applied in a one-sided fashion to move a body all points of the body will not move in the same manner, in fact, one point, or a line of points, will actually remain sensibly at rest for small displacements. This point, in mechanics, is called the *axis of instantaneous rotation,* or *the centre of percussion.*

In the case of the pendulum *B C D* nearly all the mass is concentrated at *C* and the result is that the axis of instantaneous rotation, or, as we shall call it, the steady line, is at a point very near the centre of the mass *C*. Consequently whenever the support *A* is displaced horizontally with a vibratory motion, as in the case of an earthquake, the steady line of the mass *C* will remain at rest for all movements transverse to the plane *B C D*. Motion directly in the line of the strut is communicated, of course, to *C*, but the registering mechanism is so disposed that such motions produce no record whatever. Although the mass *C* is very largely displaced whenever the support *A* is tilted even in the slightest degree in a direction perpendicular to the plane *B C D*, results have nevertheless shown that tilting is not an appreciable feature in earthquake motion, except near the origin

of the disturbance, or possibly in the case of large waves. We find then that the steady line of the mass *C* remains relatively stationary during an earthquake disturbance, and the manner of recording the movement of the earth with respect to this point is shown more in detail in Fig. 2.

The magnifying and recording lever shown at *L* is made of very thin sheet aluminum bent into an inverted trough-shaped section to secure stiffness, and is provided with a conical pointed, hardened steel, axis, *d*, which is centred and carried in the stirrup *F* which, in turn, is adjustably but firmly attached to the heavy

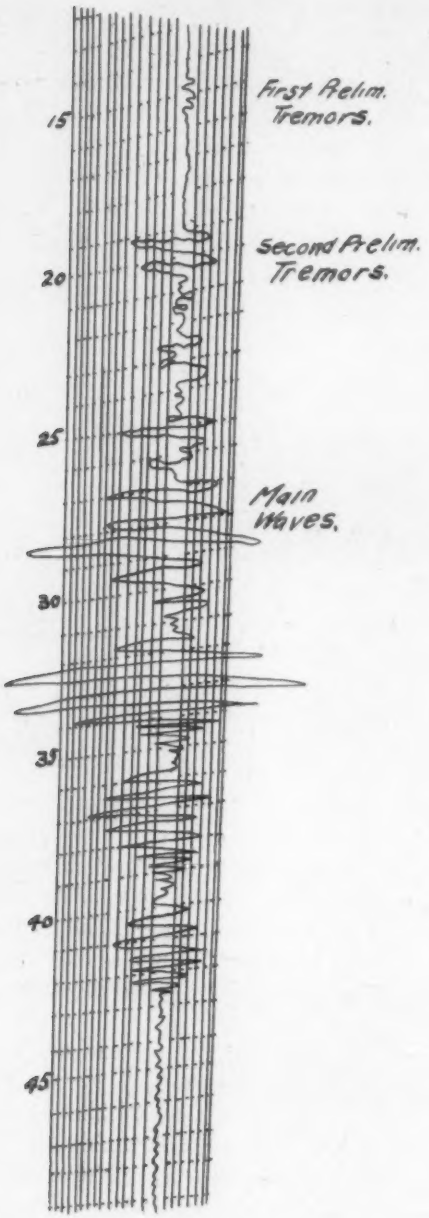
FIG. 2.



Recording and time-marking devices; original form. From originals furnished by the U. S. Weather Bureau.

casting *C*. The short arm of the lever *L* is slotted and engages the slender staff *f* in the manner shown. The staff *f* is made of hardened steel, with conical pivot points centred in the stirrup *F'*, which is securely attached to the mass *C* in such a position that the centre of the staff *f* lies in the prolongation of the steady line of the mass *C*.

The record is traced on a sheet of smoked paper wrapped around the large cylinder *R*, Fig. 1. In order that the friction may be reduced as far as practicable at the tracing point, the coating of soot is made relatively thin and a paper with a highly glazed surface is employed. Much depends also upon the tracing point which is a mere bit of steel, *s*, pivoted to the lever in the manner shown at *J*. The degree of magnification can be adjusted to suit by shifting the carrier or stirrup *F* so as to increase or



Record of a distant earthquake.

shorten the distance between the staff *f* and the pivot *d*. Provision is made for a magnification of from 5 to 15 times. A 10-fold magnification seems to give about the best results for feeble earthquakes.

DOES THE ATTRACTION OF THE SUN AND MOON MAKE A TIDE IN THE CRUST OF THE EARTH AS WELL AS IN THE OCEAN?

According to Lord Kelvin's calculation the combined pull of the sun and moon is such an enormous attractive force that it would cause a globe of steel to yield like India rubber. Astronomers have been wondering for many years whether this double attraction was not sufficient to cause a tide in the crust. The general opinion seemed to be that the crust was too rigid.

As early as 1837 Antoine d'Abbadie made a series of experiments with spirit levels to ascertain deviations from the vertical. He failed to establish anything. In 1878 Lord Kelvin tried. He used a long pendulum and a small galvanometer mirror. Twenty-five years ago Sir George Darwin and his brother Horace made an effort to measure the rise and fall of a certain point on the earth's surface under the attraction of the moon. All of these experiments failed to prove that there was a crustal tide.

It now seems as if patient efforts were crowned with success. It is alleged that Prof. Hecker, of the Prussian Geodetical Institute, has been experimenting for more than four years to prove there is a tide in the crust. Sir George Darwin is made to say in a special cablegram that "Dr. Hecker's apparatus is in a chamber cut out of the side of a wall 80 feet below the earth's surface, and he has continued to make observations by means of photography day and night for six years. It is from these observations that it is possible to determine how stiff the earth is. It is just about as stiff as if made from steel. If it were made from steel it would move up and down one-third as much as if liquid throughout."

Dr. Hecker's alleged explanation is: "When a ship mounts the crest of a wave the masts lean backward and a plummet hanging from the top of the mast will always swing from the base. Likewise if you suspend a plummet from a peak or column standing firmly on the surface of the earth, the plummet will oscillate as a tidal wave rolls along the land. If we use Von Rebeur's horizontal pendulum we are capable of recording oscillations up to a one twenty-five thousandth of an inch."

It is said that the land rises and falls between 7 and 8 inches twice a day. Flammarion states that "Prof. Hecker's experiments were made 80 feet below the ground by an apparatus of extreme precision made of two horizontal pendulums and that the deviations that had to be measured did not as a rule exceed one hundredth of a second of an arc. At the extremity of a pendulum one meter in length they produce movements which measure only a few hundred thousandths of a millimeter. In other words, they are imperceptible. How could one amplify them to make them visible? By the mode of suspension of the pendulum, by mirrors reflecting in the distance one luminous point and recording photographically the image on a cylinder. It is thus that waves are recorded twice a day like those of the ocean tides. These waves have been examined hour by hour and eventually those were recognized which were due to solar attraction and those caused by lunar attraction."

The writer knows that about 10 years ago Prof. Milne stated that no instruments have as yet revealed a tide in the crust, but that delicate instruments would some day show that there was a land wave of about one inch in 300 miles, but that it would be insignificant compared to earthquake pulsations.

This discovery that the earth's crust yields to the attractive force of the sun and moon and is actually lifted a couple of inches is of great interest and importance in the study of seismology. It may be a determining factor in the production of earthquakes, not necessarily the cause, but it may determine sometimes the time of an earthquake. For example, suppose the strata are subjected to enormous stress and tension and are about to break and form a fault, or suppose the fault already formed and the wall even recemented in the past, and then, owing to enormous stress or strain, the walls are about to part and slide either vertically or horizontally. The combined pull of the sun and moon may determine the time when it will occur, that is, when the strata will break or when the walls of the fissure will slide. It does not produce the earthquake, but determines the time it takes place.

As Le Conte aptly said years ago, it is the last straw that breaks the camel's back. If we are ever able to predict earthquakes with any degree of certainty, which is extremely doubtful; this recent discovery will be a prime factor in solving the problem.

Wm: H. Wahl

FRANKLIN INSTITUTE

WILLIAM HENRY WAHL, Ph.D.

1848–1909.

THE records of the Franklin Institute during the past thirty years epitomize the history of a period during which the arts have seemed to outrun the sciences in an onrush of advancement. The records reflect the annals of a generation during which these advances have opened the way to possibilities undreamed of heretofore. In the promotion of this great movement, the Franklin Institute, early established for that very purpose, has largely performed its part, and among the men who have had the largest share in that performance, and the one upon whom was devolved, through almost the entire period of a generation, its most immediate function, was the late Secretary of the Institute, Doctor William Henry Wahl.

Fitted for the varied duties of his office not alone by native ability and a liberal education, but even more signally by a most congenial temperament, Dr. Wahl was held to the secretaryship of the Institute by annual re-election, first for a period of four years and thereafter continuously through more than a quarter of a century; he thus became, through normal sequence, the actual leader in the Institute's activities. To those activities he devoted himself with never-ceasing earnestness, and to no one is due a larger measure of credit for the maintenance and advancement of the Institute's reputation as a focus of the applied sciences than to its widely reputed Secretary.

William H. Wahl was born December 14, 1848, in Philadelphia, and became a pupil of its public schools. In 1863, while yet but fifteen years of age, he was admitted to Dickinson College, whence he was graduated with a bachelor's degree in 1867. Following his bent for the physical sciences, he proceeded to the University of Heidelberg, then made famous as the centre of instruction in those branches of knowledge by such leaders in science as Bunsen, Kirchhoff and other masters of lesser note.

There his diligence and proficiency gained him in 1869, after two years of study, the degree of Ph.D. During a vacation visit to his home at this time he became acquainted with Professor Morton, then Secretary of the Institute, who, finding occasion to engage the services of Dr. Wahl in an editorial capacity, was thereby led to obtain from him a series of contributions to the journal of the Institute on the subject of crystallography, of which Dr. Wahl had made a special study in original researches. When, in the following year, 1870, Professor Morton retired from the secretaryship of the Institute, he recommended Dr. Wahl as being a most competent successor; the latter was thereupon elected to the position, continuing to hold it through four years, until the close of 1874. At this time he collaborated with Prof. Spencer F. Baird, of the Smithsonian Institution, in compiling the "Annual Record of Science and Industry," published by the Harpers' in the years 1874 to 1878.

During this period Dr. Wahl supplemented his work at the Institute with services, from 1871 to 1873, as Instructor in the Physical Sciences at the Philadelphia Episcopal Academy, and in 1875–1876 as Professor of Physics and Physical Geography at the Central High School. From 1873 to 1876 he was editor of the Department of Arts, Sciences and Patents of the *American Exchange and Review.* His abilities as a scientific journalist became widely recognized, and led to his becoming editor of the *Polytechnic Review,* Philadelphia, from 1876 to 1879; associate editor of the *Engineering and Mining Journal,* New York, from 1878 to 1881, an editor of the *Manufacturer and Builder,* New York, from 1880 to 1896. But it was as editor of the JOURNAL OF THE FRANKLIN INSTITUTE, a service incident to his function as Secretary, that Dr. Wahl performed his principal work in an editorial capacity, and the upbuilding of the journal from the status of a reprint of current scientific data to that of a source of original information on these subjects, has been primarily and almost solely due to the energetic efforts of Dr. Wahl.

In addition to his activity in these various directions, there may be cited as part of a long list of his contributions to the scientific literature of his time: viz., his book on "Galvanoplastic Manipulation," published in 1883; the "Techno-Chemical Receipt Book" (in collaboration), 1885; the "Hand-Book of Assaying," a translation from the German with addition of

original matter; "Constructive Arts," a synthetic treatise, in large octavo form, profusely illustrated and forming vol. v of the "Iconographic Encyclopædia, 1894;" a "Report on Petroleums, as to their Safety and Danger," for the National Board of Underwriters, New York; a valuable study on "Wasted Forces," for the *Popular Science Monthly*, 1875; "A new method for the Preparation of Metallic Manganese," and an article on the "Preparation of Metallic Alloys," both printed in the JOURNAL OF THE FRANKLIN INSTITUTE in 1893. These papers are descriptive of his investigations and development, in collaboration, of two important metallurgical processes, one for the reduction of refractory metallic oxides by means of aluminum and the other for the reduction of such oxides by means of silicon. These published investigations anticipate by several years the subsequent commercial development of the art, and are now being increasingly utilized in the steel making industry where low carbon ferro alloys are required. Wahl's process of reducing metallic oxides is similar in principle to a method of reduction which has latterly come largely into practical use, in which the oxide is mixed with powdered or granulated aluminum and ignited in a cold crucible, resulting in the reduction of the oxide and the production of a very high temperature for purposes of welding.

Among the various important services rendered to the Institute by Dr. Wahl apart from his immediate function as its Secretary, was his organization of the several individual sections of the Institute in the various branches of the applied sciences. Under his fostering influence these sections have become a principal feature of the Institute's activity. Their proceedings have largely supplemented those of the Institute in general and have enriched its journal with many records of original scientific research.

Still another, and by no means the least important of Dr. Wahl's services as organizer and leader, was his work in connection with the Institute's Committee on Science and the Arts. As ex-officio Secretary of that committee, he devoted his efforts with characteristic energy and zeal to the enlargement of its activities, and it is not too much to say that the great development of the work of the Science and Arts Committee which has taken place during the past twenty-five years, has been principally due throughout all that time to the unremitting efforts of the

Secretary, given to that end. His work in this connection would alone have sufficed to engross the labors of a less diligent hand.

Yet other of Dr. Wahl's activities in the various directions of the Institute's work remain to be recorded here. As ex-officio Secretary of the Committee on Library, his wide and thorough acquaintance with the literature of the applied sciences was a never-failing source of inspiration and guidance to that important commission of the Institute, and there, as in his other functions, he performed his part most acceptably. So too, as member of the Committee on Instruction, in which capacity, as a principal director of the Institute's school and as the immediate coadjutor of the professors and instructors, he performed a service of lasting benefit to the cause of technical education. In short, in each and all of the various functions which devolved on Dr. Wahl, partly from the nature of his position as Secretary but largely also through a readiness as willing as his abilities were thorough, he performed his part in a manner that constantly elicited the approval and frequently the admiration of his colleagues. Various honors in recognition of Dr. Wahl's accomplishments in the domain of the applied sciences came to him from time to time from various sources, but owing to his extreme reserve in relation to such matters, no definite reference to these distinctions appears in the records of the Institute. It is known, however, that some years ago, he was accorded the honor of appointment as Officer d'Instruction Publique by the French Government, in recognition of services rendered by him in a special scientific investigation.

The versatility of Dr. Wahl's talents was no more remarkable than was the peculiar combination of widely varying traits in his personality. In that respect he presented a rare example of a notably dignified presence marked by an engaging geniality —a man of impressive poise and of never-failing urbanity. He was a scholar of wide-embracing acquirements, a person of strong convictions and of liberal open-mindedness. His personality became, indeed, a veritable part of the Institute, for which, to the very end, he manifested a deep and ever watchful solicitude.

That this solicitude extended beyond his life, he evidenced in his will. Therein he provided that his entire estate (estimated to amount to about $75,000.00) be held in trust for use and benefit of his widow during her life, and that thereafter it be held for the use and benefit of the Franklin Institute, as a memorial

to his father, John H. Wahl, provided, indeed, that within three years after its reversion, an equal sum be contributed from other sources, not including bequests. Even this provision affords proof of Dr. Wahl's care for the welfare of the Institute, the provision of three years for the obtainment of the additional contribution being doubtless ample for the far-sighted purpose of the testator.

Dr. Wahl was married at an early age to Julia Lowther, a member of a prominent and cultured family of County Mayo, Ireland, but neither of his two children survived their infancy. His wife was long an invalid, and died a number of years ago. Some years later he married her sister, Mary B. Lowther, who has survived to mourn the loss of one who, having been a life-long friend, became her devoted husband.

The solicitude for all the varied interests of the Franklin Institute manifested by Dr. Wahl in all his relations to it, seemed even to increase as his activities became gradually curtailed through failing health. In the winter of 1906–1907, he suffered a collapse of the nervous system from which he never fully recovered. Several voyages to the Caribbean islands helped to so far restore his vigor as to enable him to continue at his post through the following year, but the summer of 1908, spent at his country seat at New Britain, near Doylestown, Pa., brought him to the point of resigning his position. His resignation was declined by the Board of Managers in the hope that his shattered health might yet become restored, but the ensuing winter season of the Institute was opened for the first time since 1882 without Dr. Wahl's inspiring presence. His resignation, again urged by him at this time was, on January 13, 1909, reluctantly accepted by the Board, which thereupon adopted the following resolution:

Resolved, That the resignation of Dr. William H. Wahl as Secretary of the Franklin Institute, having brought a termination to the faithful and unremitting service which he has rendered in that capacity through more than a quarter century past, the Board of Managers of the Institute enters upon its minutes this acknowledgment of Dr. Wahl's successful efforts in the furtherance of the Institute's work and this expression of regret that the condition of his health has appeared to necessitate at least a temporary cessation from his labors.

In the organization of the scientific sections of the Institute, in the promotion of its lecture courses, in the enlargement of its schools, and in the editorial direction of its Journal and other publications, Dr. Wahl has performed a distinguished part in the activities of the Franklin Institute, and left a lasting impress on its history.

As a mark of appreciation of Dr. Wahl's services as Secretary and as a member of this Board, this minute is ordered to be suitably engrossed for presentation to Dr. Wahl and to be published in the Journal of the Franklin Institute.

At the meeting of the Institute on February 17, following, on recommendation by the Board, Dr. Wahl was unanimously elected Honorary Secretary of the Institute. A record of this action was ordered to be engrossed, along with the resolutions of the Board, in a testimonial album for presentation to the Honorary Secretary. This album had but barely reached its destination when, on March 23, 1909, its recipient passed away.

With a quotation of the minute adopted by the Committee on Science and the Arts on March 24, 1909, this memoir of an earnest and able helper in the doing of the world's work may fittingly be closed:

The Committee on Science and the Arts of the Franklin Institute has learned with deep regret of the death on yesterday of the Honorary Secretary of the Institute, DR. WILLIAM H. WAHL. As ex-officio Secretary of this Committee throughout more than a quarter of a century of unremitting service, Dr. Wahl's earnest co-operation in all the various directions of this Committee's work has been a most potent influence in promoting its aims and purposes, and his associates on this Committee herewith record their sense of the great loss which the Committee on Science and the Arts has sustained through his demise.

LOUIS E. LEVY, Chairman
CHAS. E. RONALDSON,
WASHINGTON JONES,
} Committee.

FRANKLIN INSTITUTE

(Proceedings of the stated meeting held Wednesday, May 19, 1909.)

HALL OF THE FRANKLIN INSTITUTE,

PHILADELPHIA, May 19, 1909.

DR. E. GOLDSMITH, *Temporary Chairman.*

Present, sixty members and visitors.

Addition to membership since last report, 10.

The Chairman called for nominations for Trustee of the Elliott Cresson Medal Fund, to fill the vacancy caused by the death of Dr. William H. Wahl. Mr. Walton Forstall nominated Mr. E. H. Sanborn, and as there were no further nominations the Secretary was directed to cast the ballot for the meeting.

The paper of the evening on the "Present Aspects of the Panama Canal from the Tourist's Point of View" was then read by Mr. William Tatham, of Philadelphia.

The speaker reviewed the early attempts at building an interoceanic canal and gave a brief account of the work accomplished during the past few months. Attention was given to the dams and locks, to the methods of excavating and removing the earth, and to the housing and feeding of the many employes. Lantern photographs of views along the canal and scenes from Panama, Ancon, and other towns were shown. A vote of thanks was tendered the speaker for his interesting paper.

Mr. A. C. Lippincott, of the Lippincott Steam Specialty and Supply Company of Newark, N. J., then exhibited and described some new stoves, lamps, and pressing irons for denatured alcohol.

On motion the subject was referred to the Committee on Science and the Arts for investigation and report. Adjourned.

JAMES CHRISTIE,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract from proceedings of the stated meeting held Wednesday, May 5, 1909.)

HALL OF THE FRANKLIN INSTITUTE,

PHILADELPHIA, May 5, 1909.

Mr. J. Y. McConnell in the Chair.

The following report was presented for final action:

(No. 2449.) Emergency Exit Door Lock.—Hugh Elmer Clark, Rochester, New York. (An advisory Report.)

The following reports passed first reading:

(No. 2432.) Color Photography.—Lumière & Son.

(No. 2441.) Primary Battery.—Charles E. Hite. (An advisory Report.)

(No. 2450.) Boring and Reaming Tool.—Benjamin Brownstein, Trenton, N. J.

(No. 2457.) Telelectric Piano Player.—John F. Kelly, T. D. Powers, and M. R. Jewell.

(No. 2460.) Trigonometric Slide Rule.—M. J. Eichhorn. (An advisory Report.)

BOOK NOTICES

LES PLANETES ET LEUR ORIGINE par Ch. Andre, Directeur de l'Observatoire de Lyon, vi + 285 pages, 6 × 9 inches with 94 illustrations and 3 plates, 1909; price, 10 francs. Paris. Gauthier-Villars.

The object of this work is to outline the progress of astronomical knowledge from the end of the 18th century to the present time, and is divided into three main divisions—planets, satellites and the formations of planetary systems. Under the separate titles of planets named, the investigations made and the apparatus employed are described and the names of observers given.

Particular attention has been given to the motions of Venus and Mercury and to the configuration of Mars.

The subject is well illustrated, conveniently subdivided and, as in most French publications, a full table of contents is given in lieu of an index.

L. E. P.

HEAT ENERGY AND FUELS: Pyrometry, combustion, analysis of fuels and manufactures of charcoal, coke and fuel gases. By Hanns v. Juptner, Professor, Imperial and Royal Technical Institute, Vienna. Translated by Oskar Nagel, Ph.D., v + 306 pages, 118 illustrations and many tables. Price, $3.00 net. New York, McGraw Publishing Co.

The subject of heat energy, methods for its production and a consideration of the available fuels, is of the deepest interest to the technologist in any branch of industry. The appearance of a work treating the subject in a logical and comprehensive manner, containing the results of the latest researches, cannot fail to find an extended field of utility. Following the introductory chapters containing a general discussion of forms of energy and their thermodynamic relationships, the subject is classified under the divisions pyrometry, the cost of combustion and its determination, and fuels. The work abounds with tables and data, and the descriptive matter is well illustrated by cuts and diagrams. The topics included are discussed in a thorough and practical manner and deductions are consistently carried out in accordance with the principles reviewed in the preliminary chapter.

The book is of a grade that should place it among the standard works on engineering practice.

L. E. P.

LES OSCILLATIONS ELECTROMAGNÉTIQUES ET LA TÉLÉGRAPHIE SANS FIL par le Professeur Dr. J. Zenneck. Ouvrage Traduit de l'Allemand par P. Blanchin, G. Guerard, E. Picot, Officiers de Marine. Deux volumes in 8 (25-16) se vendant separement. Tome I: Les oscillations industrielles. Les oscillateurs fermés à haute fréquence. Volume de xii + 505 pages, avec 422 figures; 1909. 17 fr. Tome II: Les oscillateurs ouverts et les systèmes couples, les ondes électromagnétiques et la télégraphie sans fil. Volume de vi + 489 pages, avec 380 figures; 1909. 17 fr.

This work is based upon a series of lectures delivered by the author at the University of Strasburg during the period from 1901 to 1903 and intended principally for students of technology with limited mathematical training. The development of the subject has, accordingly, proceeded more by reference to physical and geometrical relationships than by analytical

methods, and when a complete exposition of a principle has required an application of higher mathematics, it has been treated in the notes at the end of the volume.

The first volume relates to the production of oscillating currents, beginning with the fundamentals on electromagnetic induction and developing the subject over the field usually covered in works on alternating currents, leading to consideration of high frequency oscillations required in wireless telegraphy apparatus.

The second volume is a continuation of the last chapters of the first and proceeds with the development of the methods of producing electromagnetic waves and the apparatus applicable to wireless telegraphy installations.

With the numerous commercial applications of wireless apparatus the necessity of a close study of the subject is apparent, and a work covering the field from fundamentals to commercial apparatus should have an extended sphere of usefulness.

L. E. P.

MACHINE—OUTILS. OUTILLAGE—VERIFICATEURS. Notions Pratiques par P. Gorgeu, Capitaine d'artillerie. iv + 232 pages, 6½ x 10 inches, with 200 diagrams, 1909; price 7 f. 50. Paris, Gauthier-Villars.

The present work is intended chiefly for the guidance of artillery officers engaged in inspection service. The operation, the relation of the different parts, and methods of driving of the usual types of machine tools, wood-working tools, and measuring devices are illustrated and described.

The subject is presented under four main divisions:

Part 1. Generalities on machine tools—relates to the kinematic devices employed.

Part 2. Study of classified groups of machine tools—considers the various tools embraced under the respective operations of cutting, shearing, grinding, hammering, die-pressing, and drawing.

Part 3. Cutting tools—relates to the principles involved and the manufacture of cutting tools.

Part 4. Construction and use of test-gauging instruments—describes the different forms of test-gauges employed in machine construction, methods of using, tolerances, and other matters involved in the process of inspection.

The illustrations are of the diagrammatic type only and do not purport to represent actual machines. The framing is shown in a shaded outline, the moving parts and their relation to each other being clearly defined and easily traceable, a mode of illustration excellently adapted to the intended purpose.

The powerful multi-speed drives and feed mechanisms of lathes employed particularly in ordnance manufacture are not illustrated. Indeed, the work covers a field embracing the elements of modern machine-shop equipment rather than a consideration of the elaborate mechanisms found in the most modern development of high-powered tools.

For a class of readers interested in the elemental operation of machine tools, the subject is well covered. L. E. P.

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EIGHTY-FOURTH YEAR

The Journal of the Franklin Institute

DEVOTED TO SCIENCE AND THE MECHANIC ARTS

EDITED BY

MR. LOUIS E. LEVY, Chairman; MR. EDWIN S. BALCH, MR. JAMES CHRISTIE, DR. H. W. JAYNE, MR. EDWARD H. SANBORN, Committee on Publications; with the Assistance of the Secretary of the Institute.

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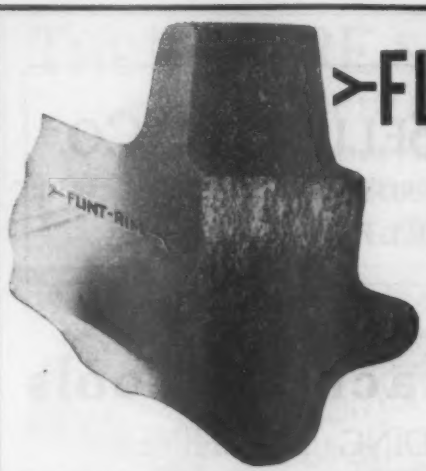

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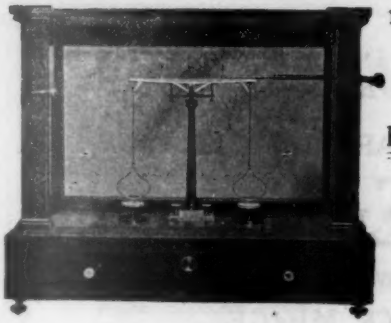

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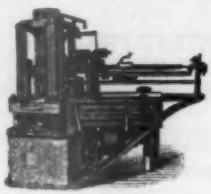

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